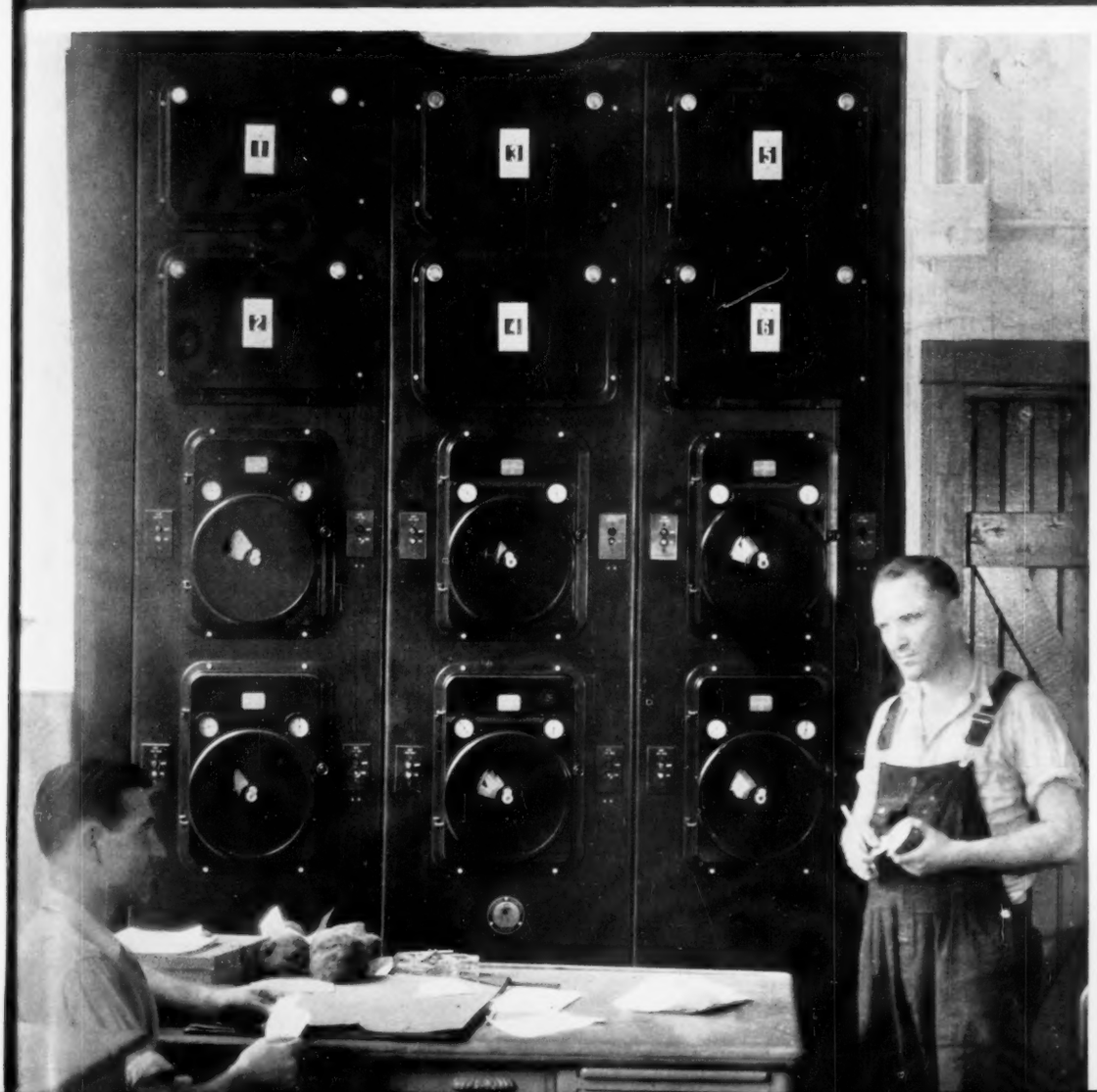
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



VOLUME 10

SEPTEMBER 1937

NUMBER 9

TAG *Saybolt* VISCOSIMETER

with

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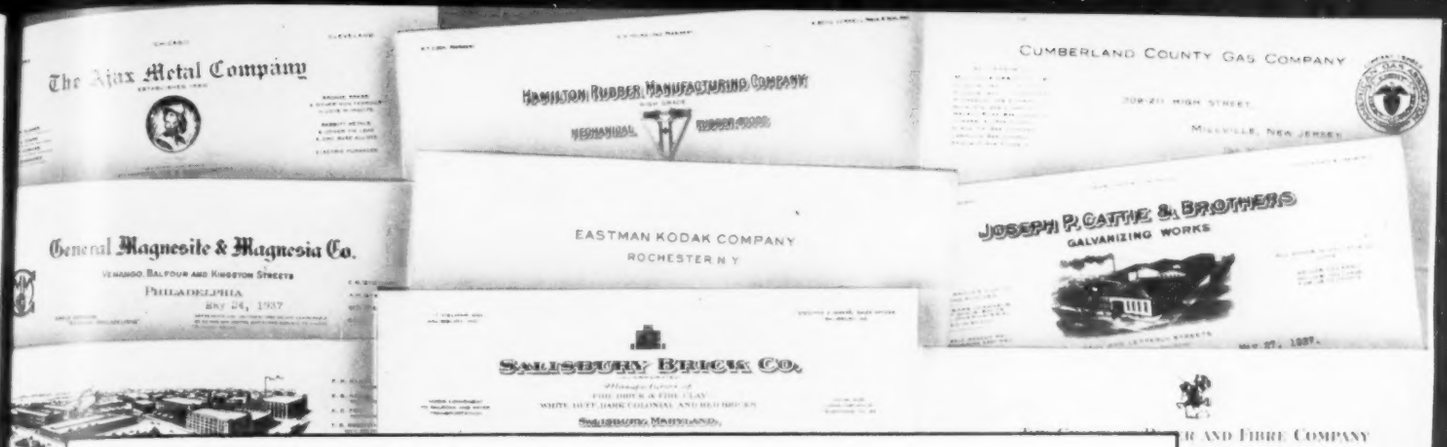

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MINNEAPOLIS-HONEYWELL Control Systems

Control is to Economize

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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at Kent Mfg. Co., Clifton Heights, Pa.
Courtesy The Bristol Co.

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

From time to time we invite specialists in certain classes of measurements to discourse on their specialties so that you may keep up with the latest technique. The result always is an exclusive article of outstanding value . . . as exemplified this month by H. H. Scott in his discussion of industrial noise measurement technique.

Dr. Williams, having covered early methods of measuring scratch-hardness, now begins a series of articles on recent methods.

New *devices* belong in our "New Instruments" Department but new *methods* of measurement and control deserve articles. So do new *classes* of instruments employing new principles. That's our policy and it's based on your interests—not on editorial-room fetishes. Hence: (1) Newman on a new method of temperature control and (2) Moore on a new class of telemetering systems.

THE FRONT COVER

shows the installation of Bristol "Coordinated Control" in the dyehouse of the Kent Mfg. Co., Clifton Heights, Pa., which makes possible the operation of Hussong dye vats under complete automatic control from the dye master's office, with benefits as follows:

Tensile strength of wool is increased 17% by the use of automatic control.

Production was stepped up 6 runs per vat per day to 10 to 12 runs per vat per day.

Now possible to get a uniform color throughout the batch, without assistance of dyer or floor man.

Amount of steam used was reduced, and steam pressure was reduced from 80 lbs. to 40 lbs.

Boiling over of vats was completely eliminated, a saving in color and chrom.

The dye master can now duplicate results with formulas previously found to be O.K.

One operation—poling—was eliminated.

Dangers Still Impend

INDICES of the nation's economic health had continued to rise. Utilization of electrical energy, for example, was breaking record after record. Judging from the numerous 1929-1937 charts flaunted by financial writers this summer, prosperity had returned and the readers of financial pages could go fishing, or loll on ocean beaches, or relax in deep easy-chairs and lazily send puffs of Havana smoke curling up to the ceiling-beams.

Your editor took his first vacation in eighteen years. He toured the Rocky Mountain and Pacific states and "mixed pleasure with pleasure" by visiting half-a-hundred subscribers along the way. All of them were enthusiastic about their work, confidently looking forward to the near future, and apparently without a single source of worry. Your editor soon forgot the activities of the anti-machine propagandists.

Devoting several evenings, after his return, to reading an accumulation of recent magazines, government publications and association booklets, your editor had a painful awakening to the ugly realities: Our enemies—your enemies—seem to have made converts among the advisers of the Administration. Not only does the introduction of labor-saving methods meet with increasing disfavor in some official quarters, but there seems to be a new kind of agitation: against the inventors who conceive labor-saving devices, and against the engineers who specify and install such devices.

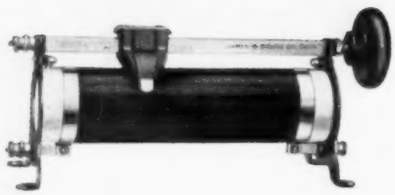
The situation at Washington is so complex as to defy analysis. Technological progress has its friends as well as its enemies. Almost simultaneously there came out two important pronouncements, one by F. Stirling Wilson of the Bureau of Foreign and Domestic Commerce and one by FDR's National Resources Committee. The former's "Technological Progress" (*pro*) was brought out with less ballyhoo than the latter's "Technological Trends and National Policy, Including the Social Implications of New Inventions" (*con*).

It would seem that pressure groups waging war on industry have changed their strategy—or that they are beginning to use strategy. They seem to have discovered the efficacy of flanking attacks, of undermining. What they demand is "planning"—which of course means hampering—the advance of technology.

You know the obvious answers: it would cripple industry to have new methods and new devices passed upon by *any* dictatorial board in Washington. Even a board of geniuses would not have foreseen in 1912 the millions of new jobs created by the new industries in this quarter-century. And *who* is the super-genius capable of selecting the geniuses that will serve as Kommissars of Inventions?

Yes, you know the answers. But the public doesn't. And the mob hates intelligence. Dangers still impend.

"JAGABI"
Rheostats



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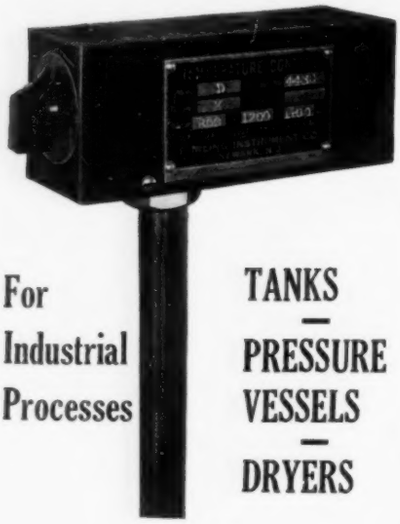

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NEW INSTRUMENTS

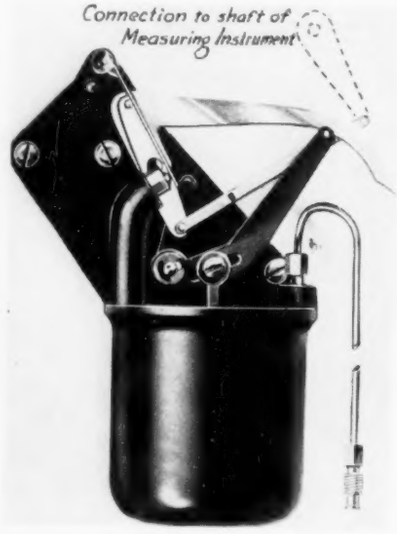
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

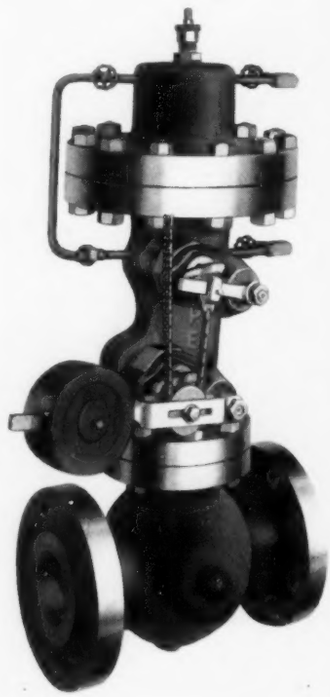
Pneumatic Telemetering Systems

There will shortly be announced a radically new remote-reading method: employing low-pressure compressed air (17 lbs./in.² supply required) for transmitting the indications of any type of measuring instrument with a pointer, pen-arm or other mechanical-displacement indicating element exerting any torque greater than that of delicate galvanometers, etc. A number of systems have already been installed and their performance under service conditions is reported to be exactly as predicted by designers and builders. Basic principle is conversion of measuring-instrument indication into a *corresponding* (but not *proportional*) pressure, 2 lbs./in.² minimum and 10 lbs./in² maximum, by means of flapper-and-nozzle follow-up of instrument indication. Receiver consists of a pressure gage of any suitable size, form, weather-protection, etc.—indicating, recording, controlling or combination—calibrated in the units measured at transmitting station. Transmitter unit proper (illustrated) is small enough to be built into the case of most 10" size industrial recorders, etc. Linkage of transmitter unit can be designed to give a scale law different from that of measuring instrument. Illustration shows a transmitter which converts the square-root law of a flowmeter into a uniform scale law. All inherent sources of error are said to be negligible. Lag is proportional to distance, amounts to fraction of second per hundred feet for a 1% sudden change in measured value.—*Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.*



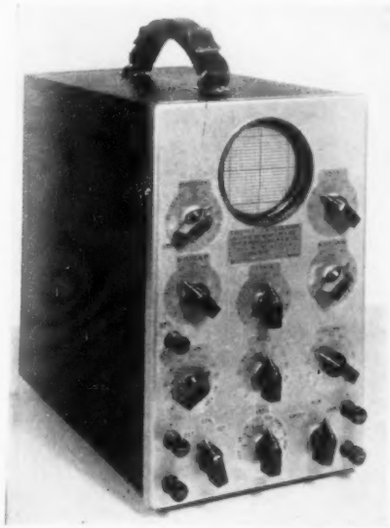
Two-element Feed-water Control

A new two-element steam-flow type of boiler feed water controller, known as the Copes "Flowmatic" Regulator, is designed for modern high-rating boilers and other units subjected to rapid, wide load fluctuations. It feeds the boiler according to the rate of steam flow, so that a higher water level can be provided on heavy loads than on light, or a practically constant level can be maintained for all ratings. It has two control elements: The steam flow controller measures the rate of steam flow by taking the pressure drop through the superheater. The water level thermostat (with tension type expansion tube as used in the standard Copes Regulator) responds to changes in the boiler water level. These two control elements are so connected mechanically to the feed water control valve that the valve is positioned by the resultant of the two forces. The feed control valve may be direct-operated or hydraulically-operated, or equipped with a motor-operator permitting repositioning by remote push button. Regulator is furnished in all pressure standards from the 250-lb. upward. Valves are furnished in 2" to 6" sizes. —*Northern Equipment Co., Erie, Pa.*



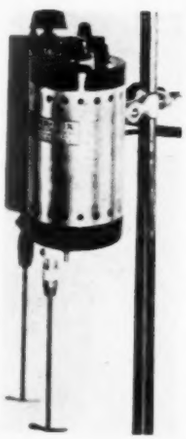
Three-inch Oscillograph

Aiming at popular appeal to justify mass production and thereby "an exceptionally low price," makers announce "Type 164" 3-inch cathode-ray oscillograph, said to embody features heretofore found only in more expensive equipment: separately controlled horizontal and vertical high-gain amplifiers, flat from 30 to 30,000 cycles; internal or external positive synchronization; high and low voltage supplies insuring a brilliant



pattern and no interaction of controls; direct connection to the horizontal and vertical deflection plates of the tube; amplified sweep; a frequency range allowing observation of a single wave form of from 15 to 30,000 c.p.s.; and separate positioning controls on the front panel. The five most essential and used controls have red knobs, while others are in black, simplifying operation. Front panel has the DuMont non-scratching and non-glaring finish. Although designed as a servicing instrument to be used in conjunction with any standard frequency modulated oscillator, it also is designed to serve the many purposes of a portable 3-inch oscillator.—*Allen B. DuMont Laboratories, Inc., Upper Montclair, N. J.*

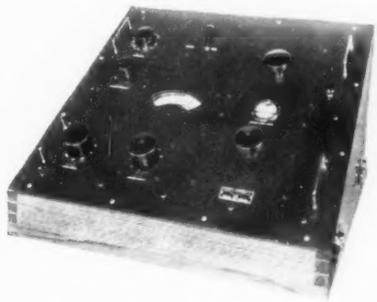
Motor Stirrer



New model Power-Mix provides finger-tip control for "hundreds of different speeds," incorporates mechanical and electrical improvements such as silent reduction gears of fabric-base Bakelite laminated, and motor end shields, rheostat knob and special fuse housing of Bakelite molded.—*Laboratory Equipment Co., 144 Lafayette St., New York City.*

Cable Power-factor Measuring Equipment

For determining quality of insulation of power cables by measuring power factor (using phase defect compensation method) this new equipment permits



testing reel lengths rapidly on a production basis. Equipment does not depend on the deflection of the wattmeter used: inductance is introduced in the potential circuit of a sensitive dynamometer, so as to reduce its deflection to zero—thus avoiding necessity for calibration of instrument. Initial zero adjustment of the power factor scale is made by applying suitable compensation, when using a high-voltage zero-loss air capacitor in place of the cable. The inductor then reads directly in percent power factor. —*Leeds & Northrup Co., 4955 Stenton Avenue, Philadelphia, Pa.*

Binocular Loupe

Three-power magnifying lenses providing stereoscopic vision are mounted on the end of a bar extending out from a specially designed spectacle frame and

bridge. A flip of the finger throws the magnifier up and out of the line of vision when desired. When worn constantly, comfort is assured by the method of construction, which permits fitting frame by changing bridge width and interpupillary distance. When user ordinarily wears correcting lenses, these may be mounted in the eyewires and the proper adjustments made for bridge width and interpupillary distance. If preferred, the loupe can be worn over regular glasses and the eyewires left blank. After the loupe is fitted the wearer can adjust the separation of the magnifying lenses to suit himself.—*Bausch & Lomb Optical Co., Rochester, N. Y.*

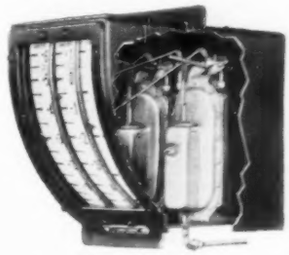
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

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Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

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Complete Information on any of the above Bailey products will be gladly furnished upon request. G-7

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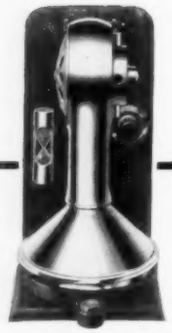

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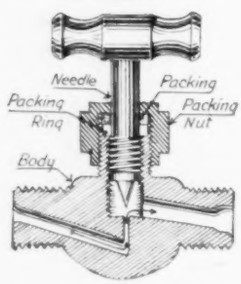

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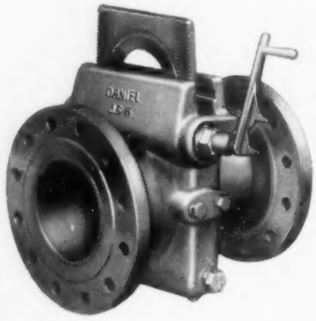
Orifice Fitting

Plate-lifting method employed in new "Junior" Orifice Fitting (Ejector Type) is same as that of "Senior" type—eliminating in the same manner the difficulties of removing orifice plate and plate holder by hand. New design is simpler in construction, is said to offer greater flexibility than any other fitting available previously, and will operate with any meter. It may be supplied with cast



flanges (illustrated) or recessed for welding, or with rigid or loose ring flanges on nipples of any length welded in. Recessed type permits field welding into meter run, with several savings.—*Daniels Orifice Fitting Co., 3352 Union Pacific Ave., Los Angeles, Calif.*

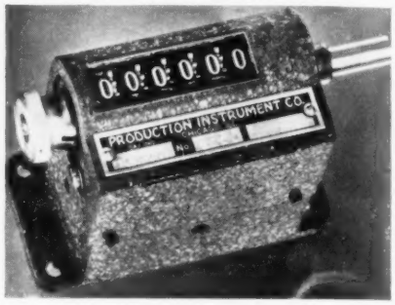
Low Loss Dielectric Measurements

A still greater degree of accuracy in the measurement of Q (power factor or dielectric constant of insulating materials and small condensers) within the frequency range of 100 kilocycles to 10 megacycles, is provided by new Type 106-A Dielectric Unit, used in combination with Type 100-A Q-Meter, which it matches in general appearance. It couples on at the right side of the Q-Meter. This combination furnishes a compact and easily operated equipment for measuring Q of extremely low loss dielectrics—quartz, for instance—and also the ordinary grades of insulating materials which may be ordinarily difficult to measure accurately. The new unit contains a highly sensitive 50-microampere indicator with necessary apparatus and

controls for setting and reading accurately. This meter is so arranged that a portion of the normal Q scale of the Q-Meter proper is thereby expanded to approximately four times normal, so that small differences in circuit Q may be readily and accurately read. The instrument also contains a line-voltage regulator for precise measurements. In combination with the standard Q-Meter, the dielectric unit measures differences in circuit Q as small as 2%, with an accuracy of about 5%. Larger differences may be measured with an accuracy of 2% or better.—*Boonton Radio Corp., Boonton, N. J.*

Mechanical Counter

New "Type MC-3-W" mechanical counter, of heavy-duty design especially adapted to counting coil winding and similar operations, has six number wheels,



is arranged for shaft drive. Count advances one number for each turn of the shaft, generally substracts for each reverse revolution of shaft. Reset knob returns all number wheels to zero with one revolution of the re-set. Frame and case are die cast, designed for convenient mounting. "Exclusive design of the drive action" prevents skip or coasting. Length 3⅝"; height 2⅝"; width 1¾"; four mounting holes 3/16" diam. spaced 1¼"×3⅛".—*Production Instrument Co., 1325 South Wabash Avenue, Chicago, Ill.*

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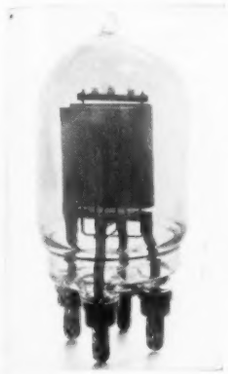
Ultra-high-frequency Tube

Especially designed for use in ultra-high-frequency or short-wave service, a new oscillator and amplifier tube finds its main fields of application for therapy, radio, and other high-frequency purposes. Usual types of tube construction have been modified by supporting the grid, filament and plate electrodes directly from short heavy rods, terminating in short thimbles which may be used to connect directly with the external circuits. (This form of basing has been used for many years on high-wattage airport flood lamps.) Other claimed advantages are low inter-electrode capacity of the tube and high conductivity of the large and short support rods. Tantalum is utilized for the anode material, having proven superior for high-frequency operation. This tube has a plate dissipation of 160 watts and is capable of delivering 400 watts of useful power up to 50 megacycles. Designated as the WL-461, this tube has the following ratings:—maximum d-c. plate voltage, 2000 volts; maximum a-c. plate voltage, 2500 volts; and maximum plate current, 250 ma. Filament voltage is 5 volts, filament current 11.5 amps. Maximum overall length is 7½".—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*



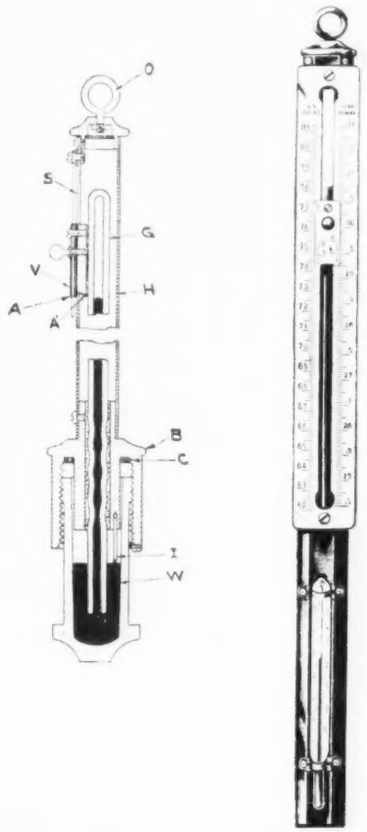
Print Hanger

Holding up to 75 blueprints, maps, etc., this print binder and hanger is made of duralumin with center hook of steel that can be turned down so that

prints may be rolled for transportation or turned back for reference. Three telescoping binder screws with a metal strip at back hold prints firmly. There are no projecting screws or sharp edges to mar prints. Renewable title strip, letter to suit, slides in a T-slot at top, is sloped at a visible angle, is protected by a strip of celluloid. Stock sizes 18", 24" and 30". Any size 12" to 48" made to order.—*Wade Instrument Co., 1663 East 118th Street, Cleveland, Ohio.*

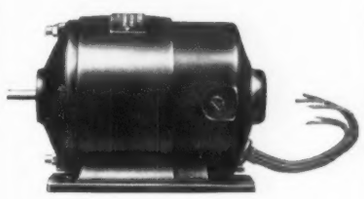
Barometer

In its general lines, new "Cenco Improved Mercurial Barometer" resembles standard U. S. Weather Bureau type, but differs considerably therefrom in design of mercury well and means of adjustment of mercury level. Instead of depending on the flexibility of a chamois bag subject to aging and eventual disintegration, new design employs a heavy clear glass mercury well flanged near bottom to provide positive grip and threaded at upper end for fine vertical



adjustment, these male threads engaging female threads in a Bakelite well mounting permanently cemented to glass barometer tube. Bakelite well mounting carries ivory index for adjustment of mercury column. A gasket permits sealing this system for transportation, sealing being simply effected by screwing mercury well tightly to its upper limit. New barometer consists essentially of seven parts: (1 and 2) well and well mounting (described above) and the following: (3) Glass barometer tube with wide bore (4 mm.) to minimize capillary depression error, scales being compensated for residual effect. (4) Brass case carrying thermometer and English and metric scales and double vernier carrying sighting points to eliminate parallax error. (5) Double reading scale covering range of 200 mm. or 8" readable to 0.1 mm. or 0.005" by means of double vernier. (6) Double thermometer, of magnifying type, graduated in single degrees C. and F. (7) Mercury of exceptional purity. A vacuum boiling process is employed in filling each barometer tube.—*Central Scientific Co., 1700 Irving Park Blvd., Chicago, Ill.*

REMOTE INDICATION *and* CONTROL



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TYPE 1 AUTOSYN MOTOR is a reasonably priced self-synchronizing motor with superior performance characteristics. One transmitter may operate as many as six receivers. Practically any system of remote indication or control may be solved by the selection of the proper type of Autosyn Motors.

FEATURES:

1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
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4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3-5/8"x3-9/16"x5-3/4".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

Complete information on request.

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Cochrane Electric Flow Meters utilize the principle and have the sensitivity of the finest measuring instrument made—the chemist's balance. This exemplifies the galvanometer null principle upon which Cochrane Electric Flow Meters operate, universally recognized by scientists as the most accurate means of measuring a force or quantity.

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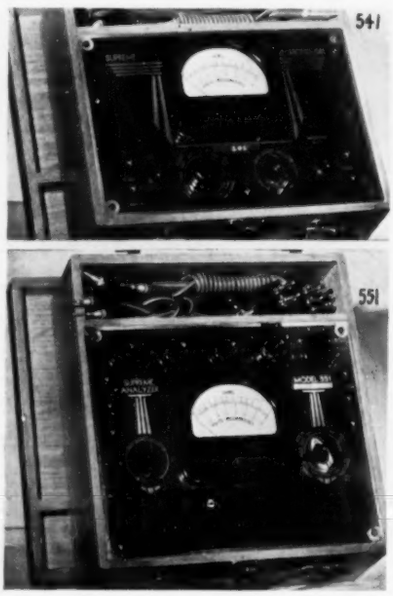
Moisture Meter

Smaller model of TAG-Heppenstall Moisture Meter is known as "Style W," is much more convenient to transport and to use. Handle and cable are stowed

in recess at bottom of case below instrument proper. Operation is as follows: "Turn right-hand switch *on;* turn left-hand switch to *STD;* adjust potentiometer until galvanometer deflects to 3; turn left-hand switch down and meter is ready for use. Jab needles into board. Turn dial switch until galvanometer again deflects to 3 and read moisture content from dial switch setting." Switch automatically turns off when door is closed. Current drain is one-tenth that of previous model: only 3 dry cells in place of 8, and they last longer.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Radio Testers

Four new testing sets are announced — all smaller, lighter and more compact than previous models. Each is designed around a new flush-panel Westinghouse instrument having a high-torque, 1000-ohms-per-volt, heavily-damped movement.

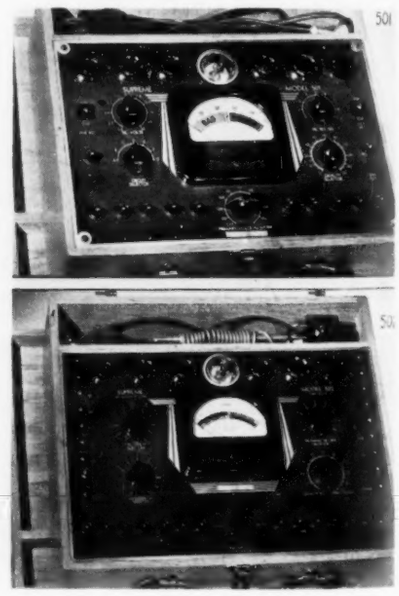


Model 541 Set Tester measures 7¼"×10¼"×4½", weighs 9 lbs., has twenty ranges and functions on a single selector switch: Four d-c. voltage ranges 0/7/140/350/1400; four a-c. voltage ranges 0/7/140/350/1400; three milliamp. ranges 0/7/35/140; four output ranges 0/7/140/350/1400 a-c. volts requiring no external capacitor; three ohmmeter ranges 0/200/2,000/20,000 ohms with 0.1 ohm as first indication and 3.5 ohms center scale reading; and two megohms ranges 0/2/20 with internal power supply. Model 541 is available for 110- to 125-volt 60-cycle supply unless specially ordered.

Model 551 Analyzer incorporates "exclusive free reference point system of analysis" whereby all resistance, voltage and current measurements may be taken between any two tube elements or between any tube element and ground or chassis without turning over the receiver. This set may also be used as a multimeter, having all the point-to-point functions and ranges of the Model 541 described above. It comes equipped with all accessories and operating data. For 110-to 125-volt 60-cycle supply unless otherwise ordered.

Model 501 Tube Tester makes possible five tests: (1) inter-element leakage between any two tube elements, (2) open element test in each tube element, (3) short check between any two elements, (4) quality test of complete tube elements, (5) separate sectional or plate quality tests of multi-section or full-wave rectifier tubes. All present types of receiving tubes can be tested. "Floating Filament" selector and associated circuit can apply filament voltage to any two pin terminations including "top cap." For 100-to 133-volt 50/60 cycle supply unless otherwise ordered.

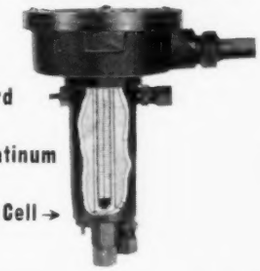
Model 502 Tube Tester is said to be not only a complete tube tester but a set tester as well. Basic tube testing circuit, same as in Model 501, is said to be obsolescence proof. In addition Model 502 offers 19 additional ranges and functions (see Model 541), also an electrostatic capacitor leakage test on a neon bulb and an electrolytic filter capacitor leakage test directly on a "Good-Bad" English reading scale. Tester weighs 16 lbs.,



measures 10½"×14½"×5", comes complete with all instructions and tube list. For 100- to 133-volts 60-cycle supply unless otherwise ordered.—*Supreme Instruments Corp., Greenwood, Miss.*

Consider this when you have

GAS ANALYSIS PROBLEMS



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Finish Tester

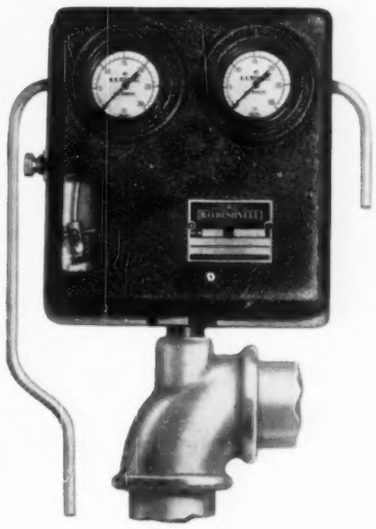
Taber "Abraser" is designed for obtaining numerical results of standardized tests on all finishes from hard metallic finishes such as chromium plate to rela-

tively soft lacquers and varnishes. By means of attachments, device permits making tests for wear-resistance, toughness, adhesion, smudge, rub-off and other characteristics of finishes, also ("reversed") for testing efficiency of abrasives. Mechanism comprises a power-driven specimen holder, a reset counter, and two pendulum arms on which are mounted standardized abrasive wheels. These wheels being eccentric with respect to specimen holder axis, abrading action is "criss-cross" and therefore represents the random-direction wear which materials receive in actual service. Wheels are standardized before start of each test by running against an unused abrasive paper disk to remove any residual matter of previous test. Toughness and adhesion are determined quantitatively by means of a weighted blade attachment. Rub-off, smudging and chalking tests are performed by means of other accessories. Still other tests are possible, combining above with "exposure" tests. —*Taber Instrument Co., North Tonawanda, N. Y.*

Multiple-orifice Flowmeter for High Pressures

A multiple-orifice flow-meter of the U-tube type, suitable for measuring a wide range of flow-rates at pressures from 200 to 600 lbs./in.^{2}, is announced. All parts subjected to stress are said to be unusually strong, and the front of the instrument is protected by a heavy shatter-proof glass plate. By loosening the gaskets of the orifice plate, it may be revolved so as to use any of four different sizes of orifice, according to the quantity of fluid being measured. The complete unit is stated to consist of a high-pressure manometer, multiple orifice plate, connecting piping, bypass valve, and wrench and cleaning brush.—*The Meriam Company, 1955 West 112th St., Cleveland, Ohio.*

H & B All-Range Temperature Controller



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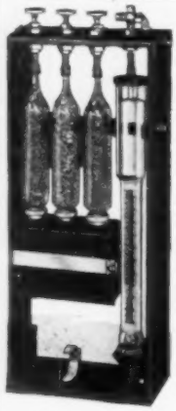

A 100 CC Orsat type analyzer with no fragile glass parts or delicate easily broken parts. Available in one, two, or three chamber styles for CO_2, CO, and O_2. Any desired scale range can be furnished. The operation is speedy and convenient. The pressed steel case is only 18¼ by 7⅞ by 4⅝. The weight of the three-chamber set, completely charged, is only 15½ pounds. Readings can be taken to 0.05%.

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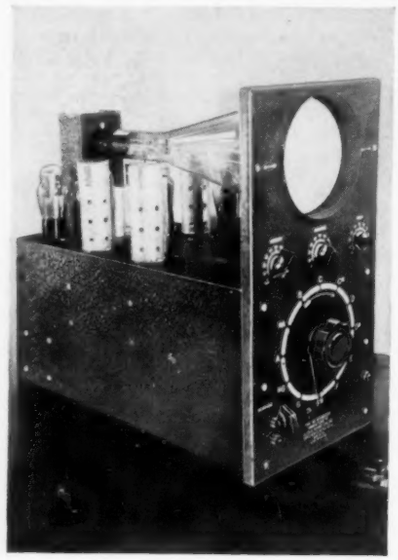

Fig. 1.

of musical frequencies representing the twelve notes of the chromatic musical scale. These standard frequencies, produced by twelve electrically-driven tuning forks, are utilized to synchronize an oscillator in step with them. The oscillator is employed to provide a horizontal sweep circuit for the cathode-ray tube. Meanwhile, a voltage amplifier is employed to pick up the music of any single musical tone and its output placed on the vertical plates of the cathode-ray tube. A special feature of the circuit is that

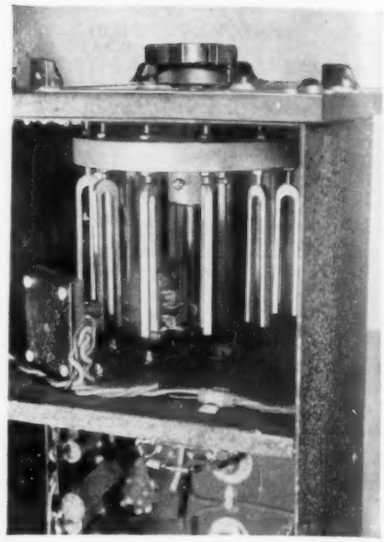

Fig. 2.

the horizontal sweep circuit is automatically changed in frequency to compensate for the change in frequency in going from one note to another. This allows sweep circuit to be readily synchronized at all times by standard frequency of tuning forks, and assures observer that the number of wave forms on the screen is a direct indication of the octave being played or tuned to. The frequencies of the standard chromatic scale are calculated for a true tempered scale, 440 cycles per second for A, but any other pitch can be had by substituting a new set of tuning forks. Fig. 1, Resonoscope with cover removed, shows front panel, cathode-ray and other tubes. Fig. 2, underneath side of Resonoscope chassis, shows master tuning forks and driving solenoids. Resonoscope permits tuning to within a minute part of a cycle. Its tuning forks are tuned to an accuracy of .002%. It also facilitates the tuning of musical instruments.—*Allen B. DuMont Laboratories, Upper Montclair, N. J.*

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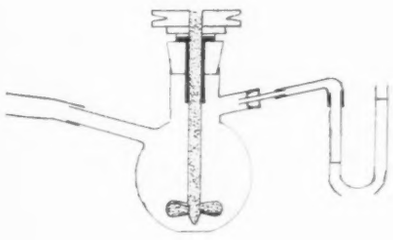
Circuit Analyzer

"Model 120 Super-Analyzer" is for measuring ave, grid bias, diode, audio, screen, and other critical voltages in electronic tube circuits. Functionalized switching, by means of positive contact rotary switches, dispenses with pin jacks and binding posts. All a-c. ranges can to be read on the same scale. D-c. voltage ranges are 3.5, 7.0, 35, 140, 350, and 1,400 volts at 20,000 ohms per volt. A-c. ranges same, with sensitivity of 7,000 ohms per volt. Ohm scales are 3,000, 30,000, 3 megs. and 30 megs. Total decibel ranges from —14 to +61 db, using five multipliers. Minimum db resistance of 35,000 ohms permits bridging of high-impedance audio circuits with negligible error. Accuracy is 2% of full-scale; circuits being designed to maintain accuracy with temperature changes. Special rectifier circuit design gives a temperature coefficient <0.05% /°C. Analyzer has all-metal, uni-welded case and snap-on cover affording complete shielding. Two 4-ft. test leads with non-breakable test prods and one push-on alligator clip are standard equipment. — *Clough-Brengle Co., 2815 West 19th St., Chicago, Ill.*

All-glass Stirrer

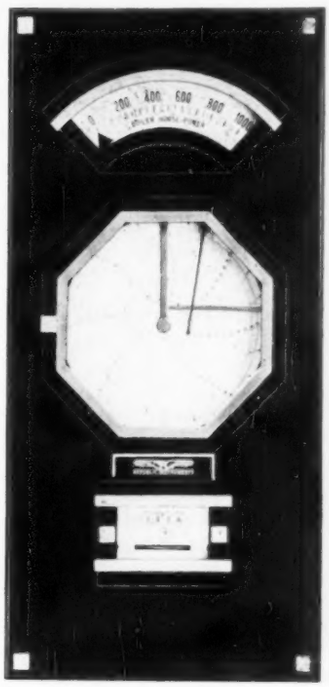
Doing away with troublesome or clumsy mercury seals, new "Jena KPG All-glass Stirrer" depends for its sealing property upon the precision fit of pro-



peller shaft and bearing tube (±0.001 mm., max. additive ±0.002 mm.). Not only is leakage prevented but impurities cannot be introduced since stirrer is all glass. Device is applicable to flasks under vacuum or pressure up to a differential pressure of 60mm. of mercury between inside and outside of flask. A slightly higher pressure may lift up shaft assembly in its bearing but no gas leakage will be observed. Lubricant is selected with consideration of operating temperature. Wear is negligible at usual speeds. 600 rpm. is recommended but at 1000 rpm., service life exceeds 1000 hours.—*Fish-Schurman Corp., 250 E. 43rd St., New York City.*

REPUBLIC FLOW METERS

- Remote Reading Type -



Republic, electrical type, flow meters are supplied for measuring the flow of all types of liquids and gases.

The indicator, recorder and integrator are remote reading and may be located any distance from the point of flow measurement. Reading instruments may be obtained in any desired combination and with related factors grouped on multiple indicators and recorders.

Meter bodies are built for all line pressures up to 10,000 pounds per square inch and for all ranges of differential pressures. Operating ranges may be easily changed by means of interchangeable range tubes and scales.

The Republic Flow Meters Co., introduced the electrical type of flow meter 27 years ago and the succeeding years of engineering research have established the Republic meter as the standard for this field. This extensive experience in metering all types of fluids is available to you for the solution of any metering problem you may have. Your inquiries involve no obligation on your part.

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Apparatus, as supplied, consists of bearing and shaft precisely fitted to each other. Inner surface dimension of the bearing tube is accurate within ±1 to 2 microns.

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R-F Signal Generator

New "Model 110" Signal Generator with an accuracy of 0.5% and a frequency range from 100 kc. to 31 mc. in five bands is announced. Direct-reading dial may be estimated to 0.25%. Dials are connected directly to condenser rotor with insulated shaft and 10 to 1 vernier, which is said to prevent slippage, remove backlash, and assure smooth drive. Permanence of calibration is assured by the use of type 2020 molded coil forms and r-f. iron cores. An air trimmer is provided for each band. The r-f. output is continuously variable through vernier control and a 4-step ladder attenuation from minimum to 100,000 microvolts on all bands. There is no uncontrollable high output tap. A uni-selector switch provides 400-cycle internally modulated r-f, unmodulated nusoidal audio voltage for amplifier tests that is adjustable 0-1.2 volts. The rotor-inductor switching is done by making all coil contacts direct to oscillating circuit. To exclude strays, entire r-f. circuit is enclosed in separate copper shielded box. Power supply and modulator circuits are independently shielded; power chassis, power supply cord, and r-f. units are said to be completely isolated by shielded, multi-section filters. The tube complement is one 76 oscillator, one 6X5 rectifier, and one 6N7 modulator. — *The Clough-Brengle Company, 2815 West 19th Street, Chicago, Ill.*

Resistor

"Type WW-5 IRC Precision Wire Wound Resistor," announced in ranges from 500,000 ohms to 1¼ megohms, is a space saver: length 1¼" and O.D. ¾",

or about half the size of present "Type WW-2." This is said to be smallest practical size for use as voltmeter multipliers, faders, gang controls, pads, etc. Standard tolerance 1%; special tolerances as low as 0.1% available on special order. Non-inductiveness, low noise levels and impregnation against atmospheric conditions are said to be characteristics.—*International Resistance Co., 401 North Broad St., Philadelphia, Pa.*

NOTE—Above illustration of "WW-5" resistor was used by mistake in connection with item on the same company's "Type CP" in our August issue, page 197.

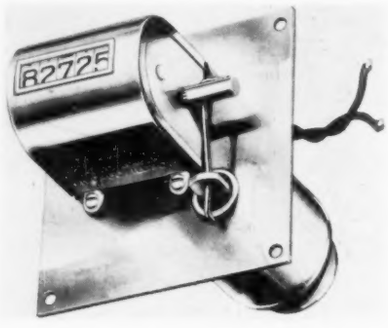
Converter Test Oscillator

The A7 type converter test oscillator is primarily intended to be used in conjunction with the typical tube bridge normally a part of the modern radio

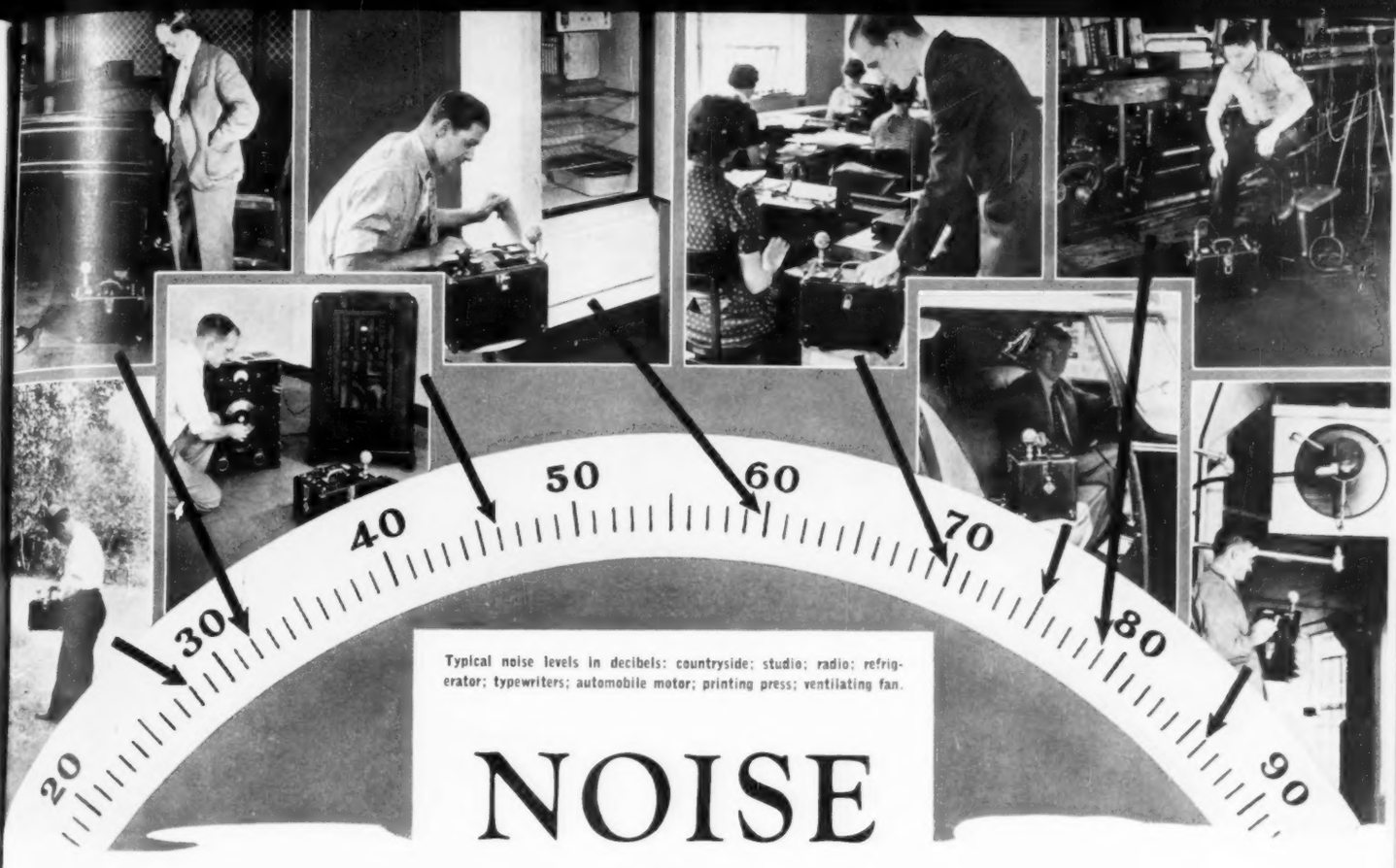
laboratory equipment. It may, however, be operated as an independent setup when connected to the essential batteries and meters. A radio receiver supplying the necessary voltages may also be used as a power supply. Three tube sockets are available, allowing measurements of six, seven and eight-prong tubes. It is also possible with appropriate adapters to make oscillation checks of triodes, tetrodes or pentodes on this instrument. —*Boonton Radio Corp., Boonton, N. J.*

Electric Counters

A new line of electrically operated counters is announced for built-in application on production machinery. The counter itself measures 1⅞"×1½"×



1¾", is mounted on a plate 2⅞" square. Operating relay is attached below base plate and extends 1⅞" below surface. Black figures on a white background, and no spaces between number wheels, contribute to legibility. Capacity is 99,999. Operating relay actuates lever arm of counter, which has a throw of ½". Positive action prevents skips or overthrow of number wheels. Steel case cover being fastened at bottom, and "Type SEC" electric counter being a non-reset instrument, tamper-proof installation may easily be made.—*Production Instrument Company, 1325 South Wabash Avenue, Chicago, Ill.*



Typical noise levels in decibels: countryside; studio; radio; refrigerator; typewriters; automobile motor; printing press; ventilating fan.

NOISE IN Industry

By H. H. SCOTT

Engineer, General Radio Co., Cambridge, Mass.

IN the last few years the psychological and physiological effects of noise have been the subject of a considerable amount of analytical study. Qualitatively, everyone has long recognized their existence through personal experience with noisy appliances in the home as well as in the office or factory. On the other hand, it is only recently that interest has been shown in determining the actual magnitude of these effects. Laird[1] has summarized much of the earlier work along these lines and has concluded that noise has diverse effects on living organisms, varying from influencing the breathing rate to the lowering of intelligence scores, and that, in general, these effects are not desirable or beneficial.

The effects of noise upon the motor functions and simple mental processes are somewhat varied. So far as the more complex cerebral functions are concerned, however, practically all evidence indicates that they are retarded appreciably by the continued presence of noise. In one test, a reduction in the noise level from 50 decibels to 40 decibels resulted in an increase of more than 30% in the speed of mental multiplication, with no impairment of accuracy. (The term "decibel," usually written "db," will be explained presently. This reduction from 50 db to 40 db represents halving the loudness. See Fig. 2.) Noise has a noticeable effect also upon the respiration and pulse rates and the emotional functions. Jacobson[2] reports that relaxation is difficult, if not impossible, in a noisy environment. Stimuli from an audiometer have been found to produce an annoyance which increases practically directly with loudness, except at high intensities, where the pitch also becomes of importance.[3]

Of somewhat more interest to industry are the actual effects of noise on the efficiency of employees. Laird cites cases in which reduction of the order of 10 db in the noise level has increased the output by as much as 12%.

Another illustration is still more striking — the assembly department of a company manufacturing temperature regulators—where the rejections were reduced to one-tenth of their former value, while the output was increased over one-third. This was accomplished merely by moving the department to a quieter location in the building. In the telephone operating room of a telegraph company, a decrease in the noise level from 50 to 35 db produced a 42% reduction in errors and also a noticeable reduction in the average cost of each message.

Similar experiences are becoming so common that less attention is paid to them now than several years ago but it seems quite apparent that a reduction of the order of 10 db in the noise level will generally result in a significant degree of improvement in efficiency and morale. A decrease of this approximate magnitude can be obtained with common types of architectural acoustical treatment.[4] This generally consists of suitable sound-insulating construction and the addition of absorbent material to the walls or ceilings, or the placing of heavy rugs upon the floor, to absorb what sound does reach the room or is generated within the room. In noisy locations, where considerable sound enters around doors or through open windows, the use of suitable seals around the doors and of mufflers or baffles in the windows will also produce an improvement which is distinctly worth while.

[1] D. A. Laird. The Effects of Noise. *Journal Acoustical Society of America*, Vol. 1, January 1930, pages 256-262.

[2] E. Jacobson. Progressive Relaxation. University of Chicago Press, Chicago, 1929.

[3] D. A. Laird and K. Coye. Psychological Measurements of Annoyance as Related to Pitch and Loudness. *Journal Acoustical Society of America*, Vol. 1, October 1929, pages 158-163.

[4] For a general idea of the improvement in noise level effected by various types of architectural acoustical treatment, see results of noise surveys (Part IV, Noise Reductions) by J. S. Parkinson, *Journal Acoustical Society of America*, Vol. 2, July 1930, pages 68-74. See also Chrysler and Snyder, Sound Transmission through Wall and Floor Structures, *National Bureau of Standards Journal of Research*, Vol. 2, 1929, pages 541-559 (Research Paper 48).

Appreciable lowering of sound levels may also be brought about by the installation of better equipment. Ventilators, fans, and heating apparatus are frequent offenders in offices, and, of course, many types of office machinery raise the sound level to an unpleasantly high value. Although the evidence indicates that fatigue caused by noise is mainly of the mental type, it should not be assumed that it is worth while to provide quiet surroundings for workers of only the white-collar class. Depending upon their habits, their hearing acuity, and the stability of their nervous system, individuals naturally react differently to various types of sounds[5]. Some observers have noted that accuracy is not always adversely affected by the presence of noise but working speed almost always is. Furthermore, as the worker becomes more tired, his fatigue is increased by noise.

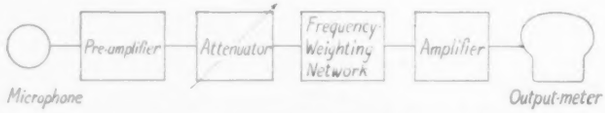


Fig. 1. Functional diagram of a system for making objective measurements of sound levels.

From this we may conclude that the sound level in offices or in any other location where the workers must exercise their mental facilities to any appreciable degree should be kept as low as possible, so that each individual can work at his highest efficiency. It should be noted that the increased working speed obtained under such conditions is accompanied by an improvement in the morale and well-being of the workers. A low noise level is not only an advantage to the employer, but promotes the mental and physical health of the employees. It is rather surprising, when a noise survey is first made in the average office or factory, to discover how high the normal noise level actually is. Usually the employees have become so accustomed to certain sounds that they hardly realize the presence of the noise which is constantly impeding their mental processes. Frequently a relatively small outlay for sound-absorbing or -insulating material, or for improved and quieter mechanical equipment, will produce an important improvement in the quality and speed of the work. A recognition of these facts by employers is resulting in a steady improvement in industrial noise levels.

Today, consumers also are demanding quieter electrical and mechanical apparatus and lower noise levels in their homes. The designers of household equipment ranging from food mixers to air-conditioning systems are attempting to keep their products as quiet as possible in order to meet the demands of purchasers and to keep ahead of competition.

The automobile industry is an outstanding example of the importance of proper attention to noise problems. As nearly all makes of cars are practically alike in mechanical details so far as the average consumer is concerned, the deciding factors in the choice of a new car frequently are its appearance and the quietness with which it operates. Norris[6] has discussed the various causes of automobile noise, including intake noise, exhaust noise, and body rumble. The production of noise in the average automobile is a complicated phenomenon, and many changes which would be expected to lower the noise level frequently make it worse. Some precise method of measuring the sounds is therefore necessary. The automobile industry realizes this, and the leading automotive laboratories have pioneered in many types of sound-level measurements, including not only the measurement of total noise level, but analyses of the sounds.

This interest in the reduction of noise has created a need for measuring instruments and has fostered an entirely new industrial application of science—commercial noise measurement. Many types of equipment incorporating various principles of operation have been developed to provide industry with definite and reproducible readings to act as a basis of comparison between different sounds. Some of the early methods involved matching an audible tone with the measured sound.[7] For instance, the audiometer, first developed by the Bell Telephone Laboratories as an instrument for measuring hearing, was applied by Lemon, Snook[8] and Free to the problem of noise measurement. The audiometer consisted of a buzzer which produced a standard noise, an attenuator and a telephone receiver. The receiver was equipped with a special plate allowing sound from the surrounding air as well as sound from the receiver itself to reach the ear of the operator. The amplitude of the buzzer-generated noise as heard in the receiver could be adjusted by means of the attenuator so that it just "masked" the outside noise. The readings of the attenuator then gave comparable measurements of sound level.

Other variations of this system included several buzzers or oscillators of different pitches. Still another form picked up the measured noise by a microphone and amplified it, and was provided with a switching arrangement so that the operator could listen alternately to the standard noise and the measured noise in order to provide a close match.

Another common method consisted of striking a tuning fork and measuring the time taken for the tone to become just inaudible.[9] The equipment required for such measurements was naturally cheap and simple, but repeated readings were necessary in order to average out the unavoidable errors and obtain reasonably satisfactory results.

Both the audiometric and tuning-fork methods involved the judgment and hearing ability of the operator and were subject to errors from these sources. In approximate surveys they gave valuable data, but, as soon as greater precision became necessary, it seemed apparent that some type of noise-measuring apparatus which was entirely independent of the human factor was necessary.

The type of sound level meter which has almost entirely superseded others for commercial noise measurements consists essentially of a microphone, an amplifier, and some sort of indicator which will respond to the audio-frequency voltages obtained from the amplifier. This system is shown in Fig. 1. Since the human ear does not respond equally to all frequencies, it is desirable to adjust the over-all frequency response of the sound level meter to approximate that of the human ear. Further, since a wide range of sound levels must be measured, the over-all gain should be adjustable, or suitable attenuators should be incorporated into the circuit, so

[5]Juichi Obata, Sakae Morita, Kinichi Hirose & Hiroshi Matsumoto. The Effects of Noise Upon Human Efficiency. *Journal Acoustical Society of America*, Vol. 5, April 1934, pages 255-261.

[6]R. F. Norris. Automotive Quieting. *Journal Acoustical Society of America*, Vol. 8, October 1936, pages 100-103.

[7]Harvey Fletcher. Speech and Hearing. Van Nostrand, 1929;
E. E. Free. Practical Methods of Noise Measurements. *Journal Acoustical Society of America*, Vol 2, July 1930, pages 18-29;
—both of these describe methods of noise measurement current at the time of writing.

[8]H. Clyde Snook. Automobile Noise Measurements. *Journal Society of Automotive Engineers*, Vol. 17, July 1925, pages 115-124.

[9]A. H. Davis. Measurements of Noise by Means of a Tuning Fork. *Nature*, Vol. 125, January 11, 1930, pages 48-49.

that a reasonable deflection can be obtained on the output meter at all levels within the range of the equipment. Objective sound level meters of this type have been variously called "noise meters," "acoustimeters," and "phonometers" but they have all been quite similar so far as the essential principles of operation are concerned.

Although all of the early sound level meters operated on practically the same principle, there were wide variations in the readings obtained with individual makes and models. Lack of any generally accepted standards for reference level, frequency response characteristics, directional characteristics of the microphone and other important factors entering into the readings made comparisons between data taken on the various types of instruments difficult or, in many cases, impossible. While the readings of many types of these meters did not duplicate closely in all cases the response of the average ear to a certain sound, they were at least definite and reproducible and were generally satisfactory for comparative work. In this respect the objective noise meter represented a distinct advance over the earlier tone-matching arrangement.

Because of the relatively high price of some of the first complete instruments on the market, many manufacturers of mechanical devices used simple assemblies of standard microphones, amplifiers, and power-level indicator meters which provided approximate measurements at but a fraction of the cost of complete equipment.[10] This method gave useful results for measuring differences in noise level, but was not convenient for absolute measurements because of the frequent and inconvenient calibration procedure necessary for such work. Unfortunately, some of the first sound level meters shared this same disadvantage.

Early types of sound-measuring equipment gave manufacturers of mechanical devices and acoustical materials a convenient means for comparing their products with those of other makes and, except in a few border-line cases, the readings obtained generally showed which product was actually the best from a standpoint of quietness. Lack of standardization, however, made it impossible to compare readings taken with different types of meters because of their differing characteristics. This was of no great importance at first, but when it began to seem desirable to incorporate noise level data in purchase specifications, and when manufacturers began to advertise the low decibel ratings of their products, the need for standardization became obvious. Unless the type of noise meter and the conditions under which the measurements were made were carefully specified in each case, the noise ratings were practically valueless, since it was impossible to duplicate the readings or to compare them satisfactorily with the ratings of other manufacturers.

Many early noise meters[11] read directly in decibels above the average threshold of hearing at 1000 cycles (approximately 0.45 millibar) and contained a single weighting network giving an over-all frequency response not greatly different, throughout the most important parts of the range, from the low level characteristic specified in the new standards. There was, nevertheless, no general agreement among manufacturers and users of noise meters regarding reference levels and frequency characteristics. The various levels constituted only a minor annoyance, since it was possible to compare readings taken with respect to one level with readings referred to another level by merely adding or subtracting a fixed number of decibels. For instance, another common reference level at that time was 1 millibar, which is approximately 7 decibels higher than the average threshold of hearing. A meter calibrated in this manner read 7 decibels less on any given sound than a similar instrument calibrated with respect to the average threshold, providing, of course, that the instruments were alike in other respects.

Unfortunately, however, two different makes of meters were seldom alike in other characteristics. Any appreciable differences in frequency response produced variations in readings for which it was almost impossible to compensate. Furthermore, practically all of the microphones used had pronounced directional properties, that is, their response at various frequencies depended upon the direction from which the sound was coming. In some applications, it was possible to point the microphone at the source of the noise, thus minimizing directional errors, but for measuring sound in automobiles, airplanes, etc., this was impossible, since the sound was coming from all directions. As a consequence, noise measurements made with different types of meters could be compared only roughly, if at all. This condition was well understood by both manufacturers and users of noise meters but was the cause of considerable confusion among consumers.

ESTABLISHMENT OF STANDARDS FOR MEASUREMENTS AND INSTRUMENTS

As a result of this situation, the American Standards Association, at the request of the Acoustical Society of America, undertook to develop a set of standards for noise measurements and for sound level meters.[12] Practically all companies interested in sound level measurements, either as manufacturers or as users of the equipment, were represented on the coöperating committees, and a set of tentative standards has recently been approved. The rapidity with which the new standards are being adopted indicates the general desire to clarify the sound-measuring situation. Apparently no serious difficulties are being encountered in meeting the important points in the new standards and it should be possible to compare the readings made with the new sound level meters with a satisfactory degree of accuracy.

Briefly, the new tentative standards specify the units in which the sound level meter shall read and the standard reference level, as well as the over-all frequency response characteristics and the dynamic characteristics of the indicating instrument. Standard procedure is also outlined for minimizing the differences of readings caused by the directional characteristics of certain types of microphones.

As has been customary for some time with sound level meters, the unit of measure is the decibel, which represents a logarithmic ratio.[13] Such a scale was selected since, although the response of the ear is neither strictly logarithmic nor linear, it does approximate a logarithmic characteristic. The actual relation between loudness as estimated by a large number of observers and loudness

[10] H. H. Scott. Inexpensive Noise-measuring Equipment. *General Radio Experimenter*, Vol. 7, September 1932, pages 1-4.

[11] H. H. Scott. Commercial Noise Measurement. *General Radio Experimenter*, Vol. 7, March 1933, pages 6-7.

[12] See American Tentative Standards for Noise Measurement (Bulletin Z24.2-1936) and American Tentative Standards for Sound Level Meters for Measurement of Noise and other Sounds (Bulletin Z24.3-1936) published by the American Standards Association.

[13] The number of decibels represented by any given power ratio is given by the formula: $db = 10 \times \log_{10}(P_2/P_1)$ where P_2 and P_1 represent the two powers being compared. In cases where the impedances are equal, sound pressure (or, in electrical systems, voltage) may be used in a similar formula, as follows: $db = 20 \times \log_{10}(E_2/E_1)$ where E_2 and E_1 represent the sound pressures being compared (or, in electrical systems, the voltages being compared). An idea of the actual magnitude of the ratio represented by any given number of decibels may be had from the fact that twice the power equals approx. 3 db, while twice the sound pressure equals approx. 6 db. Similarly, ten times the power equals 10 db, while ten times the pressure equals 20 db.

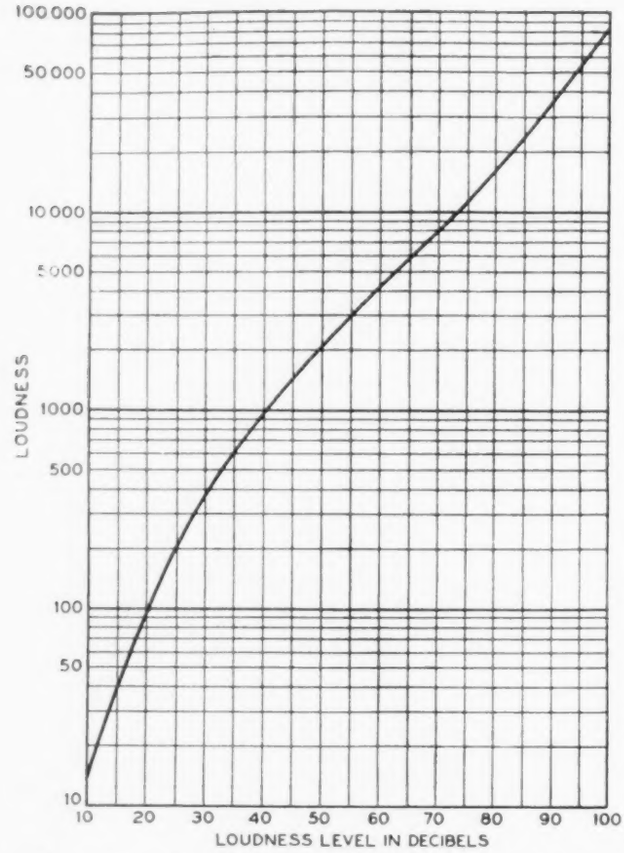


Fig. 2. The relation between loudness and loudness level as measured by a new standard sound level meter. (from A.S.A. Bulletin Z 24.2-1936).

level measured in decibels is shown in Fig. 2. It will be seen that the decibel scale is quite satisfactory for all practical purposes. In the region where sound measurements are generally made, that is, from 25 or 30 db up to 100 db, the curve is quite close to a straight line.[14]

Since the decibel is a logarithmic unit, a decibel reading as such has no absolute significance, representing merely a ratio. Accordingly, some reference level must be selected from which to measure the decibel readings. Recently a reference point somewhat lower than those previously used has become widely used, and it is this level which has been adopted for the tentative standards. This reference sound intensity is 10^{-16} watts per square centimeter at 1000 cycles in a free progressive wave, and is about 7 db lower than the average threshold of hearing,[15] or 14 db below 1 millibar. Accordingly, the readings of previous types of sound level meters which meet the new standards in other important characteristics can be referred to the new reference level by merely adding the proper number of decibels to all readings.

It is a well-known fact that the response of the ear is not uniform to sounds of different frequencies. The average ear is most sensitive in the region around 2000 cycles and considerably less sensitive at extremely high or low frequencies. Furthermore, the relative response of the ear to different frequencies is not constant with sound level. As the sound level increases, the relative response to the extremely high and low frequencies increases so that the frequency characteristic becomes more nearly uniform.

In early sound level meters it was customary to adjust the over-all frequency response so that the reading of the meter on a complex sound would roughly approximate the response of the ear to a similar sound. This meant that the various frequencies were weighted to different degrees before being added together by the indicating instrument to give a single integrated measure of the sound. It was common practice to use a single frequency-weighting network which would provide a reasonable compromise over the entire range of the instrument, since obviously no single network could duplicate exactly the response of the ear over a wide range of intensities. Accordingly, the weighting network generally followed the characteristic of the ear somewhere in the region of 40 or 45 db. For an appreciable range in either side of this value, such a network was quite satisfactory, but obviously for high sound intensities the response to extremely low or extremely high frequencies was insufficient to duplicate the ear response with an appreciable degree of accuracy. Because of this, the more elaborate types of sound level meters were equipped with an extra frequency-weighting network for use at high sound intensities in order to give a more even response over the audible frequency range.

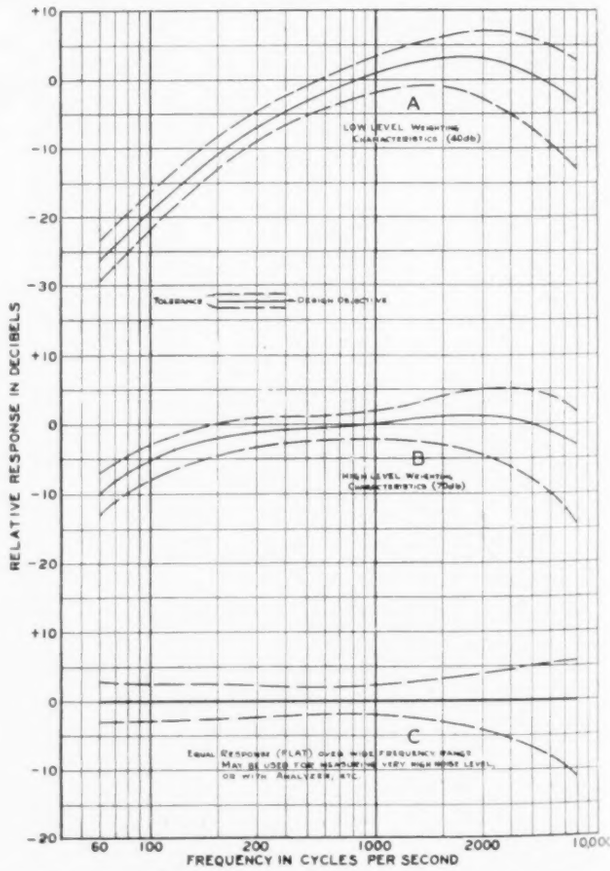


Fig. 3. Over-all free field frequency responses and tolerances for sound level meters as specified in the tentative standards of the American Standards Association.

[14]For further information on the response of the ear to sounds of various intensities, see
Harvey Fletcher and W. A. Munson. Loudness, Its Definition, Measurement, and Calculation. *Journal Acoustical Society of America*, Vol. 5, October 1933, pages 82-108;
P. H. Geiger and F. A. Firestone. The Estimation of Fractional Loudness. *Journal Acoustical Society of America*, Vol. 5, July 1933, pages 25-30;
L. B. Wam and J. S. Parkinson. Loudness and Intensity Relations. *Journal Acoustical Society of America*, Vol. 3, April 1932, pages 511-534;
D. MacKenzie. Relative Sensitivity of the Ear at Different Levels of Loudness. *Physical Review*, Vol. 20, 1922, pages 331-348;
R. R. Riesz, "The Relationship Between Loudness and the Minimum Perceptible Increment of Intensity. *Journal Acoustical Society of America*, Vol. 4, January 1933, page 211-216.

[15]For further information on the threshold of hearing, see L. J. Sivian and S. D. White. On Minimum Audible Sound Fields. *Journal Acoustical Society of America*, Vol. 4, April 1933, pages 288-321.

Curve A, Fig. 3, shows the low-level characteristic as specified in the new standards. If a sound level meter has only one weighting network, it should correspond to this curve which represents the so-called 40-db equal-loudness contour modified by the difference between normal and random free field thresholds. Where an additional high-level network is included, it should follow the curve marked B, which represents a similar characteristic at a level of 70 db, or optionally, the high-level network may provide an equal response over the entire frequency range. Many users of sound-measuring equipment are of the opinion that all three networks should be included in a sound level meter since readings taken with the 70-db characteristic and the flat characteristic will differ somewhat, particularly when the sounds include extremely low or high frequencies. When the three networks are included, the 70-db characteristic may be used for measurements around a 70-db level while the flat characteristic may be used for measurements at higher levels, that is, around 100 db or more, where the response of the ear is more nearly uniform, particularly at the lower frequencies. Of course, a sound level meter having all three characteristics can be used for making measurements to be compared with those made with any other standard type of meter. In cases where the two meters do not provide the same frequency characteristics, this is not always possible.

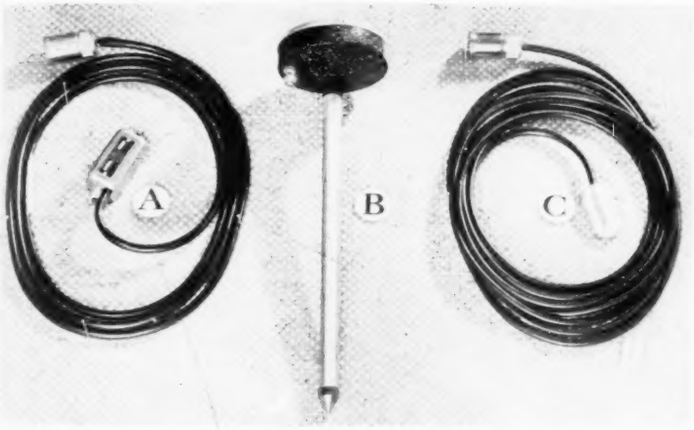


Fig. 4. Three common types of piezoelectric vibration pick-ups.

The manner in which the apparent loudness of a complex sound varies with the intensity of the different component frequencies is extremely complicated. For purposes of standardization the American Standards Association has decided that a sound level reading on a given complex sound should represent approximately the sum of the powers of each of the components. The usual type of rectifier circuit used in sound level meters does not meet this requirement exactly and, accordingly, tolerable deviations are included in the standards.

The dynamic characteristics of the indicating instrument are also specified in the new standards. Briefly, a sound lasting 0.2 second or longer should give practically the same maximum reading as a constant sound of the same intensity. When, however, a sound lasts for 0.1 second or less, the reading should be appreciably lower than that which would be obtained on a constant sound of the same level. Furthermore, the meter should not overshoot noticeably on sudden sounds. These characteristics approximate roughly the response of the ear to transient noises, and what is more important, they provide a definite characteristic which all noise meter designers will try to duplicate so that different makes and models of instruments will give practically the same readings on sounds of varying intensity.

With all manufacturers of sound level meters attempting to follow as closely as possible the new A.S.A. standards, it becomes apparent that there should not be appreciable differences in sound-level measurements made with any of the new standard meters. The various types of sound level meters on the market at the present time show a high degree of similarity in their general design features and operating characteristics, and it is mainly in matters of convenience of operation or in operating characteristics of a more or less secondary nature that any important differences will be found. For instance, assuming that a sound level meter meets the new standards satisfactorily, it is also highly desirable for most applications that the instrument be light and portable and that it be operated from self-contained batteries so that it can be used in practically any location. The use of batteries naturally makes it necessary for the designer to take into account the fact that the voltage of the batteries will vary as they wear out and compensating adjustments such as filament rheostats, etc., should be provided or, what is more convenient, the circuit may be designed so that it will remain relatively stable regardless of normal changes in battery voltages and resistance. Ballast tubes and self-compensating amplifier circuits using multi-element tubes have been successfully applied to the problem.

Other important features of modern sound level meters are nonsusceptibility to alternating electromagnetic fields or to strong mechanical vibrations. The first feature is the result of careful shielding of all transformers or inductances, or designing the circuit so that they are not necessary. The second feature is obtained by a proper shock-absorbing suspension for the vacuum tubes so that any sounds picked up by the tubes directly will cause a response in the sound level meter circuits so small as to be negligible compared to the voltages obtained from the microphone.

Many accessories may be used with a sound level meter in order to increase its scope of usefulness. Among these, the vibration pick-up is one of the most common. Such a device measures solid-borne vibrations rather than air-borne vibrations such as a microphone responds to.[16] A vibration pick-up is, accordingly, of considerable value when tracing sounds to their sources. These pick-ups are generally of the piezoelectric variety, although units working on the electromagnetic or dynamic principles are also sometimes employed. Typical piezoelectric pick-ups are shown in Fig. 4. Those marked B and C operate on the inertia principle, that is, the piezoelectric crystal is fastened firmly to the pick-up shell at three corners and the inertia of the crystal causes it to bend when the shell is vibrated. Over a range of frequencies below the natural resonance point of the crystal a device of this sort has an output voltage which is approximately proportional to the square of the frequency. The output depends upon the acceleration of the vibration pick-up. A pick-up of this type has the important advantage that it is unusually rugged and unaffected by ordinary abuse.

Another common type of vibration pick-up is that shown in Fig. 4A. In this type, a small plunger deflects

[16] H. H. Scott, Using the Noise Meter with a Vibration Pickup, *General Radio Experimenter*, Vol. 9, April 1935, pages 1-2.

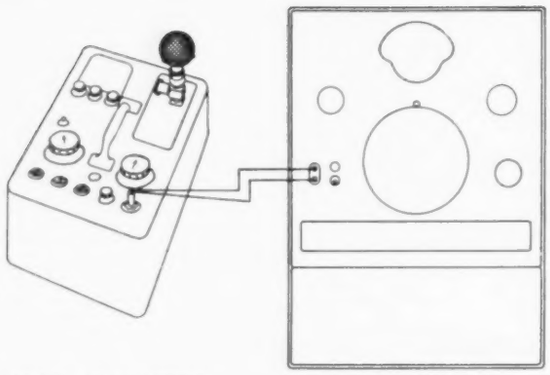


Fig. 5. A wave analyzer may be used with a sound level meter in order to determine the amplitude and the frequency of the various components of a sound.

the crystal and the voltages generated are roughly proportional to the amplitude of the vibration for frequencies below the resonance point of the crystal. When the sound level meter has a flat frequency characteristic, this type of vibration pick-up can be used for measuring approximate vibration amplitudes. Unfortunately, no commercial types of vibration pick-ups available at the present time have as even a frequency response characteristic as would be desirable and, accordingly, they should not be relied upon for exact measurements. Users report that some vibration pick-ups of this general character are not always as rugged as the inertia-operated type, but the fact that the output is reasonably independent of frequency over a wide range makes the plunger-operated pick-up extremely useful for many purposes. One point should always be borne in mind when using a plunger-operated vibration pick-up. With this type of unit the shell should be mounted rigidly with respect to the vibrating body. Otherwise, a serious error may be introduced into the readings, particularly on low-frequency vibrations, due to movement of the pick-up shell itself.

Although vibration pick-ups are still in a stage of development where frequent and important improvements can be expected, there are many applications where these devices are practically indispensable. For instance, when checking the operation of extremely small mechanisms such as electric clocks, it frequently is impossible to obtain a sufficiently low value of background noise for microphone measurements to be really useful. Under these conditions, the use of a vibration pick-up held against the clock case will frequently provide readings entirely satisfactory for production testing and which would be quite impossible with any other simple arrangement.

ANALYZERS

Aside from measuring the actual level of a noise, it is sometimes desirable to analyze the sound into its component frequencies. Various devices have been applied to this problem, ranging from variable filters or sets of filters covering relatively wide frequency ranges to wave analyzers passing a band of only a few cycles.

Some types of sound level meters have been provided with jacks or terminals so that filters or analyzers may be inserted into the circuit and most other types of sound level meters can be adapted for such use, if necessary. Wave analyzers of the type frequently used for the analysis of electrical waveforms can be connected directly to the sound level meter (see Fig. 5) and will provide a reasonably accurate analysis of sound. Fig. 6 shows

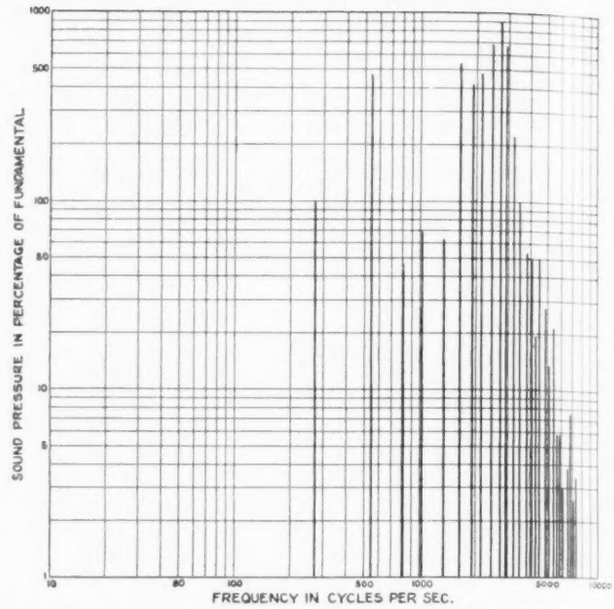


Fig. 6. Analysis of automobile horn tone made with equipment as shown in Fig. 5.

the analysis of an automobile horn tone as made on an analyzer of this general type. In order that a sound may be analyzed accurately, it is essential that the pitch and amplitude remain fairly constant. Otherwise, the selectivity of a sharply-tuned analyzer makes it impossible to obtain satisfactory readings. A broader tuning analyzer or a set of filters will, of course, provide readings on varying sounds and will give an idea of the approximate distribution of the energy throughout the frequency spectrum. For many types of sound measurements, therefore, a broadly-tuned analyzer or a set of filters is more satisfactory than an extremely selective analyzer, although the latter instrument will provide more accurate readings on constant sounds.

Now that sound level meters and the methods of making noise measurements have reached a reasonable degree of standardization, it is expected that an ever-increasing number of industries will find uses for these instruments. The new standard sound level meters make it possible for the industrial engineer to make satisfactory noise measurements as easily as he makes light intensity measurements with a photoelectric light meter. The sound level meter provides a means for definite comparison between various sounds of different pitches, amplitudes and harmonic structures and, in most cases, the readings will check closely with the average of a large number of aural observations made by persons with normal hearing. There should no longer be any doubt as to which automobile or electric fan runs most quietly under a given set of operating conditions. Neither should there be any doubt whether or not the sound level in any office or factory is above the average for other locations of similar character or above a desirable level. The modern sound level meter is not a complicated piece of scientific equipment requiring a trained engineer for operation, but a simple, convenient and—considering what it accomplishes—relatively inexpensive device which can be operated easily by almost anyone and which can be applied to a practically infinite number of problems.[17]

[17] A more complete description of "The Technique of Noise Measurement" will be found in Bulletin 20, **General Radio Co., Cambridge,** Mass.

Recent Scratch Hardness Methods

Ninth instalment of "Hardness and Hardness Measurements." See page 1, Jan. 1937 issue.

By S. R. WILLIAMS
Professor of Physics, Amherst College

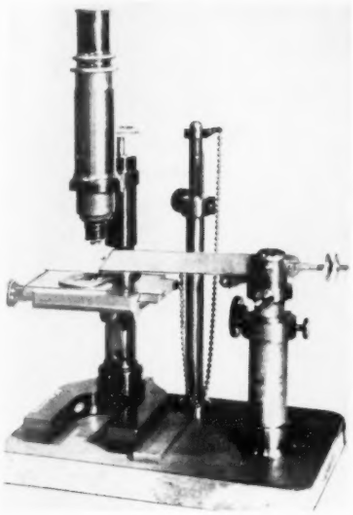


Fig. 50. A form of the Graton design as constructed for the laboratory of physics in Amherst College. Duralumin beam, fused glass bearings for beam and chainomatic balancing as devised by Christian Becker, Inc., are among the new features added.

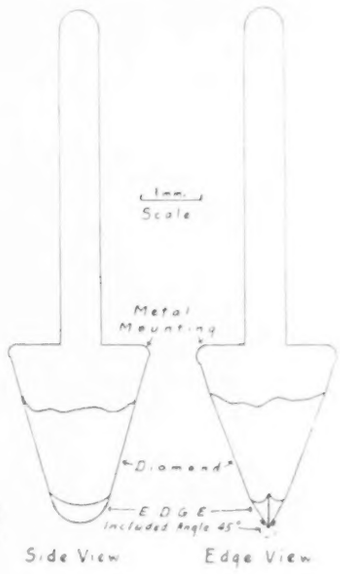


Fig. 52. Diagram of diamond point used in Graton's sclerometer.

GRATON'S SCLEROMETER

Among the more recent forms of sclerometers may be mentioned the one built by the Geophysical Laboratory at Washington according to designs emanating from the laboratory of Economic Geology at Harvard University. Fig. 50 shows the complete outfit as recently designed, while Fig. 51 gives a close-up of the main part of the instrument as designed at the Harvard laboratories. This figure shows the balance beam and the sliding weight whereby additional load is put on the scratching point.

By replacing a steel needle with a diamond edge, shown in Figs. 52, 53a, 53b, it was found that a "gratifying constancy had been secured." "In addition to the extensive tests and checks applied by Talmage,[1] this means of measurement has been used during several months by other workers in this laboratory and found to be essentially practical in application and independent of the personal equation." Thus writes L. C. Graton in a prefatory note to Talmage's article. Warning is given: "The simplicity of the scheme, however, must not obscure the necessity of application under rigidly standardized conditions."

The hardness of ore minerals possesses importance because of the hope that hardness tests may be developed for assisting in the identification of minerals—particularly opaque ones—as refractive indices have been used for transparent minerals.

A review of Talmage's paper makes clear that scratch hardness is about as varied as any field of hardness testing. One also gets the same idea from the various definitions suggested for scratch hardness. The Standard Dictionary defines hardness as that "quality of a mineral that resists scratching." Dana[2] defines hardness as "the resistance which a smooth surface offers to abrasion." Iddings[3] varies the definition by saying that

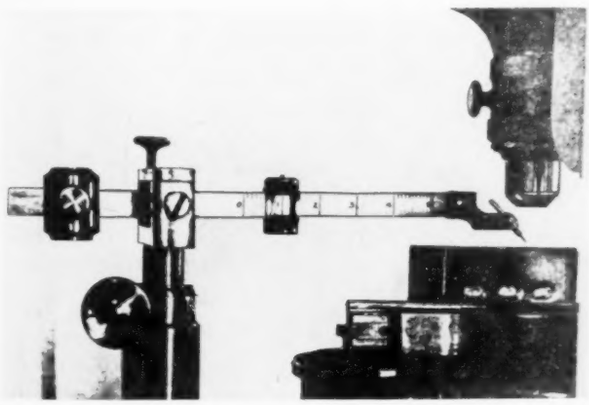
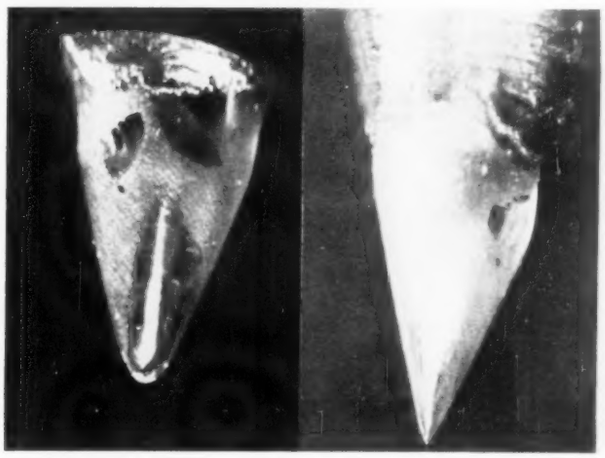


Fig. 51. Scratch hardness tester as devised by L. C. Graton and improved by S. B. Talmage.



(a) (b)

Fig. 53(a). Side view of the diamond point as furnished for the Graton sclerometer, built for the laboratory of physics, Amherst College. (Photograph of unused condition.)
Fig. 53(b). Edge view.

[1] S. B. Talmage. Quantitative Standards for Hardness of the Ore Minerals. *Economic Geology*, Vol. 20, 1925, pages 531-553.
[2] E. S. Dana. A Textbook of Mineralogy. John Wiley & Son, New York, 1922, pages 191-194.
[3] J. P. Iddlings. Rock Minerals. 2nd edition. John Wiley & Son, New York, 1911, pages 84-86.

"hardness is the resistance offered by the cohesion of the molecules to their being torn apart by abrasion." Jaggar[4] adds that "hardness is the resistance which a substance opposes to permanent deformation by abrasion, penetration, friction or fracture."

Murdoch[5] has suggested that minerals be limited to three degrees of hardness as shown by a scratch sclerometer. The steel needle is to be 5 inches long and weigh a quarter of an ounce. With such a needle the first class of minerals will be scratched just by the weight of the handle carrying the needle; perhaps a slight pressure might be added. These are soft or low-hardness materials. The second degree of hardness, the medium one, would be represented by that class of minerals which would be scratched faintly by a light pressure, but easily scratched with moderately heavy pressure. Those minerals having a degree of hardness called hard or high-hardness would constitute the third class. This classification does not afford as many steps as Mohs' and mineralogists have already tried to introduce fractional steps in that scale.

TALMAGE'S METHOD

Talmage seems to have come nearest to reducing the scratch method to a practical system than any of the investigators using this type of sclerometer. He measures hardness in terms of the load necessary to give a constant width to the scratch. For a standard of scratch width, Talmage cuts two parallel scratches on a small piece of glass which may be inserted in the eyepiece of the microscope used in observing the scratch made on the material whose hardness is to be measured. These two scratches have sufficient difference in width so that the scratch made by the diamond edge will fall between these standard limits. Talmage found it easier to establish a width of line to fall between these standard limits than to try to make the scratch identical with one standard line. The field of view in the microscope is shown in Fig. 54. The standard width of scratch established by the two lines on the comparison scale located in the eyepiece is a wholly arbitrary standard, and yet it is a standard. If two machines were to be compared it would be necessary to compare the standard scratches and to find some conversion factor between the two. A close approximation to a standard scratch could be made by using a standard load on a standard diamond point on a standard kind of glass, all of which would be arbitrary as before.

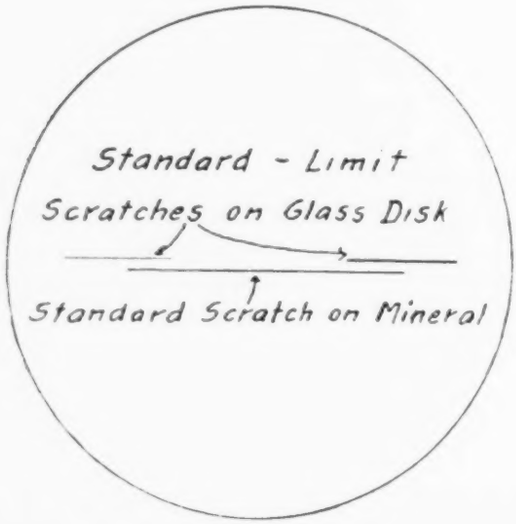


Fig. 54. Standard scratches with which to compare the scratch on a mineral.

In the light of Wollaston's work[6] it would appear that Talmage, in standardizing his diamond edge as shown in Fig. 52, had found an excellent form of diamond edge for making a scratch. This is confirmed by the fact that the diamond edge has remained perfect throughout a fairly long period of use.

As shown in Fig. 52 the diamond edge is so ground and the shank holding it is so set that the surface scratched forms a tangent to the edge of the diamond at the point of contact, or at least it should be so set. This seems rather an important point.

In his work, Talmage established six different standards for the use of the instrument, and it is to these standards that Graton referred in his warning given above. These standards are:

(1) Standard point, a diamond edge with an included angle of 45° (See Fig. 52);
(2) Standard light from a No. 37213 Spencer microscope lamp (Variations in intensity made a great difference in judging scratch width);
(3) Standard direction of scratch, parallel to plane of illuminator;
(4) Standard optical equipment, 16-mm short-mounted objective, 5× eyepiece and prism illuminator;
(5) Standard tube length, 160 mm;
(6) Standard width of scratch between limits ruled on eyepiece disk (See Fig. 54).

Having established these standards, Talmage was able to obtain "highly consistent results." In his work it must be remembered that a mineralogist is working with minerals, materials which run over a long range—all the way from talc to diamond in Mohs' scale. It is because of this wide range that Talmage argues for the variable-load constant-width scratch sclerometer. The question can be raised, should this type be used by the metallurgist with metals, or the physicist can be more general and query: is the Graton instrument a universal instrument for hardness measurement?

On the establishment of a sclerometer with "gratifying constancy," Talmage proceeds to set up a new scale of hardness for minerals to correspond to Mohs. Instead of numbers 1 to 10, Talmage uses letters A to G inclusive. The minerals which he thus lists, are

Designation of group	*Type Mineral*	*Hardness No. actual weight on point*
A	Argentite	0.105 grams
B	Galena	0.210 "
C	Chalcopyrite	0.365 "
D	Tetrahedrite	0.520 "
E	Niccolite	0.775 "
F	Magnetite	1.035 "
G	Ilmenite	1.550 "

If one takes Franz's tests[7] on Mohs' crystals, it is quite evident that Talmage has selected a set of minerals with more regular steps than those composing Mohs' minerals. Values of the hardness of the minerals composing Mohs' scale, as measured by other methods, will be compared with one another in a subsequent article.

To be continued

[4] T. A. Jaggar. A Microsclerometer for Determining the Hardness of Minerals. *American Journal of Science*, Vol. 4, 1897, pages 399-412.

[5] J. Murdoch, Microscopical Determination of the Opaque Minerals. John Wiley & Son, New York. See also W. M. Davey & C. M. Farnham. Microscopic Examination of the Ore Minerals. McGraw-Hill Book Co., New York, 1921.

[6] W. H. Wollaston. On the Cutting Diamond. *Philosophical Transactions of the Royal Society*, Vol. 106, 1816, pages 265-269.

[7] R. Franz. Ueber die Härte der Mineralien und ein neues Verfahren dieselbe zu messen. *Annalen der Physik und Chemie*, Vol. 80, 1850, pages 37-55.

A Method of Inherent Time-lag Compensation for Automatic Room-temperature Control

By L. J. NEWMAN
Electrical Engineer, Meyer, Strong & Jones, Inc., New York

GENERAL CONSIDERATIONS

IN the transfer of heat from the source to the point of utilization there is a time lag, the value of which is dependent on the following: (1) the rate of response of the source, (2) the rate of heat transmission, (3) the rate of absorption of both the medium heated and the control instrument. The choice of an automatic temperature controller should take into consideration such time lag.

In any thermal system consisting of source, "application" and automatic controller, a change of temperature at the point of utilization must necessarily be out of phase with a change at the heat-producing source. Any system of automatic control for a heating system must therefore inherently maintain an out-of-step condition by proper timing to prevent abnormal departure from desired values. The rate of change of temperature in any part of the system is important. An increase in rate of change will tend to cause over-heating and under-heating unless such rate of change is checked.

Any automatic controller must control the temperature of a room between two limits, a maximum and a minimum, which we call the differential. The room thermostat is adjusted to start the application at the source at a given temperature, say 69° F., and to shut such application at say 71° F. The two-degree difference is the differential. This amount can be varied up or down. A similar differential is obtained with a snap action thermostat and is the difference in temperature between the make, which may again be 69° F., and the break at a higher temperature, or 71° F. This rise produces the force necessary to overcome the action of a permanent magnet or the tilting of a mercury switch. The range of the instrument is the adjustment for a different level of temperature, such as made at night, maintaining the same differential. For example, this may be 59° F. and 61° F. respectively corresponding to the day setting of 69° F. and 71° F.

An ideal automatic controller would be one which would tend to maintain a continuous flow of heat in direct proportion with the rate of heat loss at any moment, and which would instantaneously adjust the heat input to changes in such loss. This cannot be accomplished for reasons later explained.

THERMOSTAT REQUIREMENTS

The room thermostat should detect a change in temperature and cause adjustment at the heating source an appreciable time *before* either the minimum or maximum limit is reached; in one case causing an increase in heat input during a fall in room temperature, and in the other case causing a fall in heat input during a rise in room temperature. The net effect would be the control of the rate of change at both ends; the regulator having the function of checking the rate *before* the minimum or maximum limit of room temperature is attained. It is evident, therefore, that as the room temperature approaches the minimum or maximum setting of the thermostat, the rate of change in temperature should have been reduced to such an extent as to tend to reduce the deviation from the differential values in either direction. If such deviation does occur, the regulator should open up the heat source fully in one case or shut it down completely in the other case.

In other words, the proper control of a heating system is the control of the *momentum* of heat produced at the source.

USUAL TYPE OF HUNTING

The automatic control of heat always produces cyclic changes in both the producing means and in the heat distributing fluid, as well as in the room temperature. There is *always* a *definite* lag between *each* of these. This is clearly shown in Fig. 1 and Fig. 2. Fig. 1 is for a forced-draft warm-air system with oil burner and Fig. 2 is for a hot-water system with coal furnace and natural draft. The scales of these curves differ.

It will be noted in both these curves, that the room temperature shows a maximum when the rate of change of the register air supply or water temperature is a maximum on the down grade. The same relation exists in a reverse manner on a fall in room temperature. It should also be noted that the actual lag in time varies with the cycle in a given system as the frequency varies with weather changes. As the weather gets colder, the cycles are shortened. The analogy to an alternating current is evident. We can say that the phase relations are in close approximation as follows: The room temperature curve lags 90° behind the curve of the heating distribution medium and the latter lags 90° behind the heat production in the furnace, the heat in the furnace, therefore, being 180° out of phase with the room temperature.

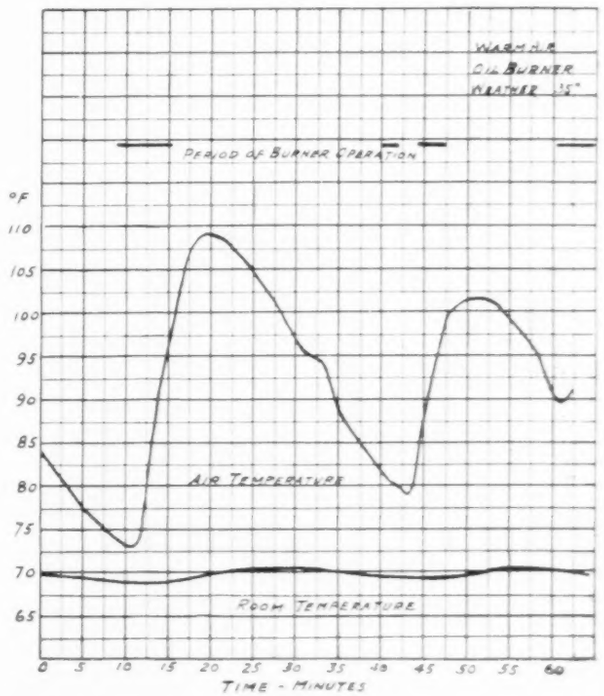


Fig. 1

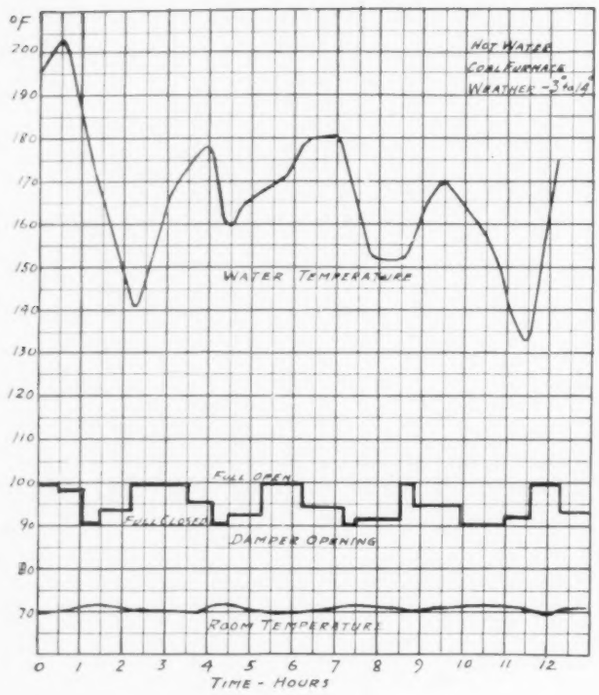


Fig. 2

This relation is true regardless of the system of heating or the method of control.

From the above analysis, it will be clear that when the natural period of change is long, close differential setting does not help much to improve control. Long natural periods are due principally to slow response of production or heat input at the source and slowness of circulation of air in the room. Short natural periods are due to quick response at the source as well as fast circulation of air. The time period of the thermostat must be added to the other time factors.

USUAL COMPENSATING DEVICES

To prevent excessive swings in temperature, anticipating features are introduced to check production or cut it off completely before the room temperature has reached a value at the upper limit of the thermostat. This is usually done by some clock device or the time functioning of an electric heating element. The clock timing device, with a mechanical shifting arrangement, changes the range of the thermostat slowly up and down the amount of the differential during a period of 20 minutes. This causes contact to be made one way or the other if the room temperature is within the zone between the upper and lower limits. The heater type of anticipator is in the form of a small electric heating element, which is put in circuit when the thermostat makes contact calling for heat. This artificially heats the bimetal strip, causing premature shut down of heat input before the room temperature has changed to cause such adjustment under normal operation. Both of these try to foretell what the future temperature effect will be.

THE NEW METHOD

We have seen, from actual data shown in the curves, that heat input, heat output and the effect on the room thermostat are not in synchronism. Automatic temperature control must allow for this condition. The greater the storage capacity for heat there is in the system of heating, the more need is there for compensation to prevent hunting.

Now let us consider the ideal of inherent lag compensation. The approach to the ideal for close temperature control may be warranted for process work, where the value of the product would absorb the cost. But for commercial or residential heating requirements, comparative low cost of control equipment is essential. An approximation of the conditions for an ideal controller will give the desired results for this class of heating.

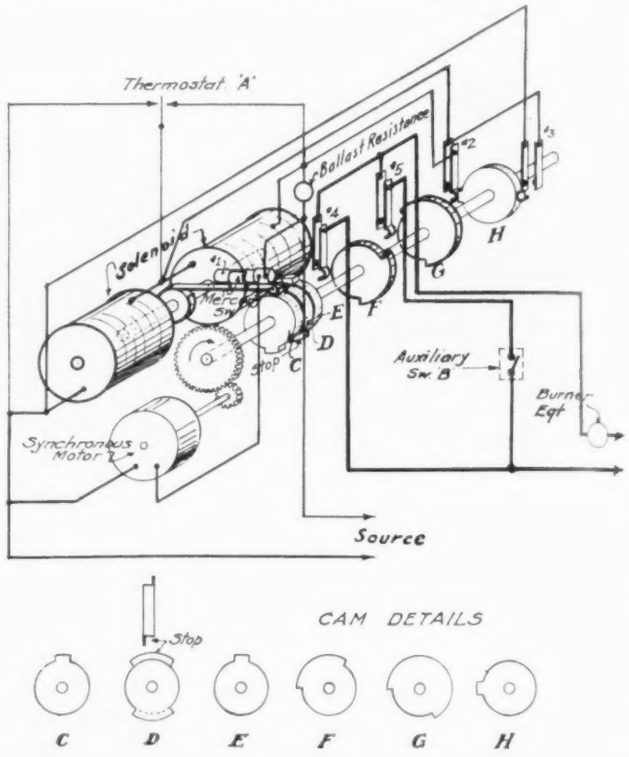


Fig. 3

From a practical standpoint, extremely close temperature control is not required. The measure of good control is the feeling of comfort of the occupants of the space heated. A feeling of discomfort may be due to other conditions than temperature, such as humidity, currents of air or what is known as "cold 70." A continuous flow of heat (even though not uniform), by preventing rapid rate of change in temperature, tends toward more comfort than the "on-and-off" intermittent action of a heating system.

The following method of control overcomes the objection of rapid rate of change by controlling the production at the source by means of auxiliary apparatus which utilizes the opening of the thermostat circuit to change the rate of production or to control a period of operation. It operates both at a rising as well as at a falling temperature, there being an abrupt decrease in production at the maximum rate on the rising side and similarly an abrupt increase on the falling side.

Two methods of control are shown in Fig. 3 and 4. Fig. 3 is a time period control and Fig. 4 is a positioning control, where the arm may be stopped at several predetermined positions.

The thermostat A is a plain three-wire instrument. The solenoid relay for both figures is identical. Thermostat contact on the cold side pulls the core to the left and contact on the hot side pulls the core to the right. Open circuit restores the core to the center. It will be noted that the two coils are connected in series with a ballast resistance. The thermostat terminals are con-

nected between the two outside points on the coils and the common point of the coils. Contact of the thermostat blade short-circuits one of the coils, the other coil is actuated and pulls over the core, upon which the mercury switch 1 is attached, closing the motor circuit. The motor operates until one of the cams stops the motor. It will be noted that cam H short-circuits the second solenoid

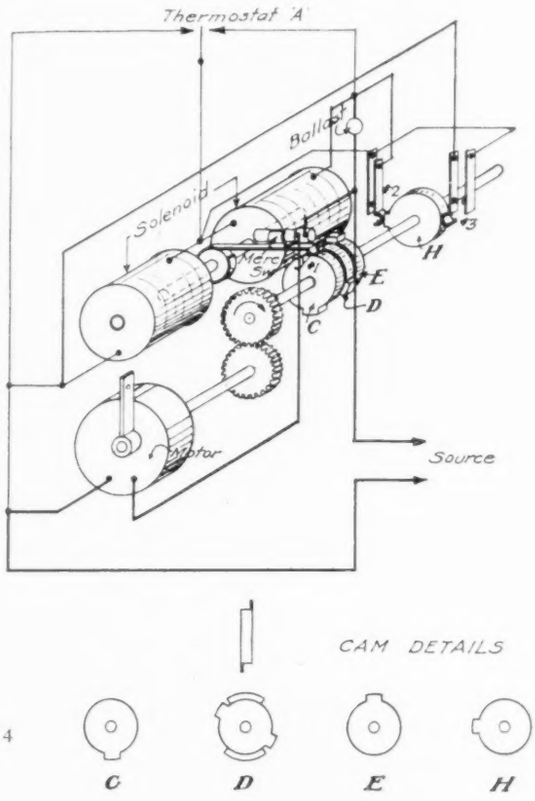


Fig. 4

coil through contact 2 or 3 at the end of travel, leaving the ballast resistance alone in circuit. On the opening of the thermostat circuit, the solenoid coil which had been first short-circuited is energized and pulls the core back to the middle cam D, a projection on the cam preventing motion of the core beyond the center. The mercury switch again closes and the motor operates to give an intermediate result: in Fig. 3 to run as a timer, in Fig. 4 to stop at one of the predetermined positions.

It will be noted that the operation of the relay is entirely electrical, no springs being required. There are three reasons for this: (1) The power required to operate is relatively small, this being essential to prevent heating the thermostat blade. (2) An a-c. solenoid with springs, that will not be noisy, is expensive to build. (3) Chattering is eliminated due to rapid make and break of thermostat contact.

Switch B in Fig. 3 serves to select the intermediate setting when thermostat A is on open circuit. This switch may be manual or automatic in operation or may be a separate instrument like an outside thermostat. It is evident that the number of points on switch B may be made any number. (Fig. 4 does not show switch B but this can be applied to give similar results.)

The operation as a time control as shown in Fig. 3 is evident from the diagram. When thermostat A is on the hot side, cam C stops the motor and the burner circuit is open through contacts 4 and 5 operated by cams F and G. When the thermostat is open, cam D allows the motor

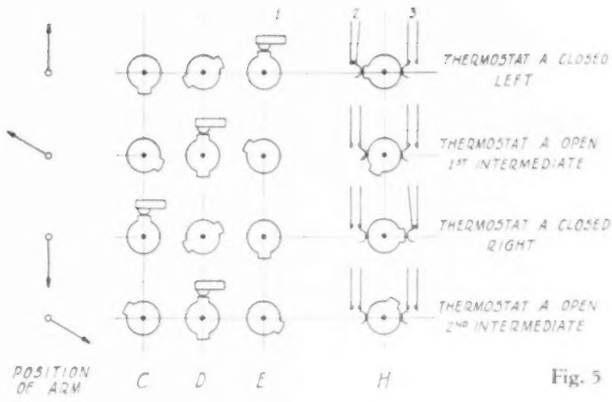


Fig. 5

to run continuously, the time cycle being determined by cam F or cam G, whichever is in circuit through switch B. If the cam shaft makes one revolution in 15 minutes, cam F will be "on" for 5 minutes and "off" for 10 minutes and cam G will be "on" for 10 minutes and "off" 5 minutes. When thermostat A is on cold side, cam E stops the motor and the burner circuit remains closed through contacts 4 and 5.

The operation as a positioning control is shown in Fig. 4 and is similar to that described above. The mercury switch serves to start the motor, the stopping point being determined by the position of the projections on cams C, D, and E. The sequence of positions is shown in Fig. 5. This figure shows four positions, but it is evident that any number of positions can be arranged for by the use of a multi-contact switch and cams as shown in Fig. 3.

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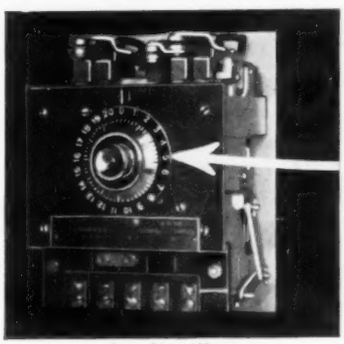

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EAGLE SIGNAL CORPORATION

MOLINE ILLINOIS

Pneumatic Telemetering

By COLEMAN B. MOORE

Development Engineer, The Brown Instrument Co.

ELECTRICAL telemetering, or the remote transmission of instrument readings by electrical means, is well known in industry. There are many methods in common use.* There are also several types of hydraulic systems. Pneumatic transmission, however, appears to have been neglected. It is the purpose of this article to describe a system for the remote transmission of flow-rate readings by pneumatic means and to show how this method can be adapted to telemetering pressure, temperature, etc. In the transmitter of this system, the instantaneous indication of the flowmeter is "translated" or "transformed" into (or "expressed as") a *pressure*. The receiver of this system is a pressure gage, graduated in units of the flow being measured at the transmitter.

Air-operated automatic control instruments which operate diaphragm valves and dampers without the use of relays or auxiliary motors have shown the simplicity of such an installation. They have demonstrated also the flexibility of a pneumatic system to meet the specific requirements of the process to be controlled. It must logically be assumed, therefore, that an air system which can accurately and quickly transmit the measurement of a variable to the centralized control board or "control house" should find an equally wide field of applications in industry. A little exercise of the reader's imagination should extend this principle, even outside the field of instruments, to other industrial uses.

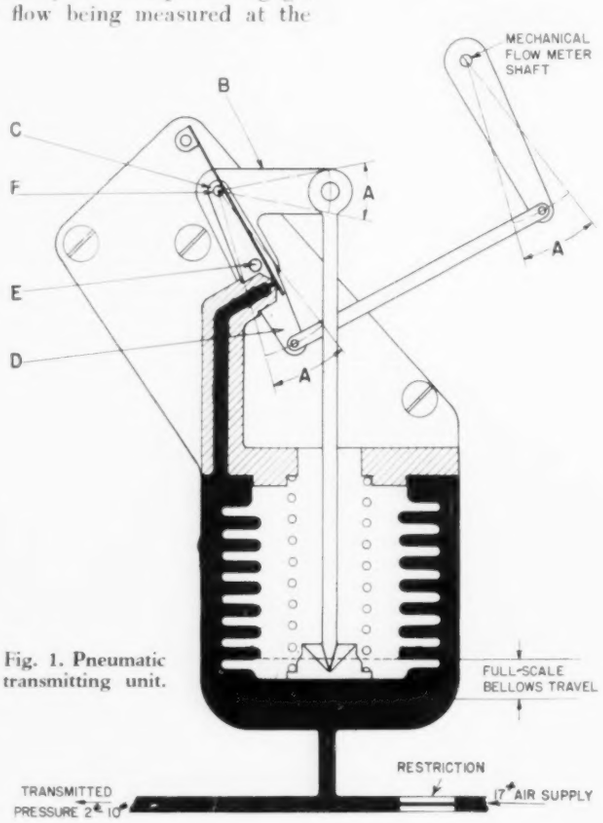

Fig. 1. Pneumatic transmitting unit.

KINEMATICS OF PNEUMATIC AMPLIFICATION

Elementary mechanical problems involving levers and gears have taught us that if we wish to amplify a given motion, it is necessary to sacrifice power in the inverse ratio. Practical experience also shows a proportionate loss of accuracy due to backlash.

Likewise, amplifying the power means a corresponding reduction in motion and loss of accuracy.

A pneumatic system using a sensitive pilot (such as the flapper-and-nozzle) has a useful characteristic, in that it can simultaneously amplify power and motion without any appreciable decrease in accuracy.

The torque required to operate the pilot is only a few centimeter grams. Since a 0.003″ movement of this pilot is sufficient to change the transmitted pressure over its entire range, the possibilities for amplification of motion are numerous.

Operating forces are taken up in the same direction, so that backlash is eliminated.

OPERATING PRINCIPLE

Fig. 1 shows the construction of a pneumatic flow-rate transmitter. The flowmeter shaft, operated from a float in a conventional mercury manometer, rotates for full scale through an angle represented by *A*. The transmitter bellows must therefore operate through its connecting rod to move the flapper-actuating mechanism through the same angle. The spring and the bellows are so proportioned that a change in pressure from 2 to 10 lbs./in.^{2} will accomplish this motion.

The flapper-actuating mechanism consists of a bell crank *B*, with a fixed pivot at *C*. This bell crank carries a lever *D*, pivoted at *E*. To the lower end of lever *D* is attached a link connected to the arm from the flowmeter shaft, and the upper end of the lever carries a projecting pin *F*, which operates the flapper. In the zero flow position, when the transmitted pressure is 2 lbs./in.^{2}, the flapper is about 0.004″ from the nozzle.

In operation, a counterclockwise motion of the arm from the flowmeter shaft (corresponding to an increase in flow) moves the lever *D* about its pivot, causing the flapper to rest on the nozzle and build up the pressure in the bellows chamber. The compression of the bellows moves the bell crank *B* to restore the flapper to a position slightly closer to the nozzle. This balances out the mechanism at a proportionately higher pressure, bringing the system to equilibrium.

In actual operation, these motions occur simultaneously, so that the flapper-actuating levers work as a unit and move through the same angle, following the motion of the flowmeter shaft arm.

The pressure connections consist simply of a regulated and filtered 17-lbs./in.^{2} air supply connected through a restriction to common connections to the transmission tubing, bellows chamber and nozzle. The restriction is smaller than the nozzle opening, so that when the flapper is about 0.004″ from the nozzle, the pressure will drop to 2 lbs./in.^{2}, and when it is about 0.001″ away, the

*P. A. Borden and M. F. Behar. Telemetering & Totalizing. *Instruments*, Aug. 1935, pages 207-210; Sept. 1935, pages 235-240; Oct. 1935, pages 256-260; Nov. 1935, pages 293-296; Dec. 1935, pages 323-332; Jan. 1936, pages 11-23; Feb. 1936, pages 43-48; March 1936, pages 82-85.

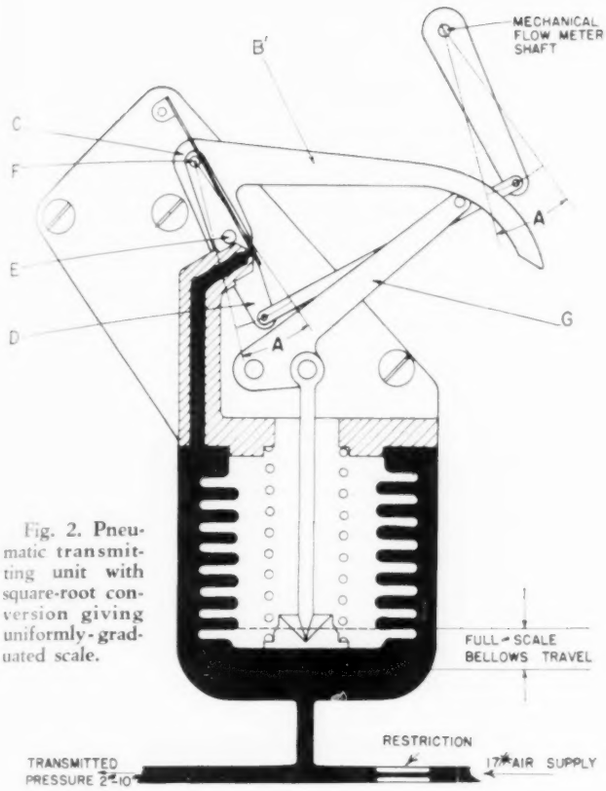

Fig. 2. Pneumatic transmitting unit with square-root conversion giving uniformly-graduated scale.

pressure will rise to 10 lbs./in.^{2}. The receiver, therefore, is an accurate pressure gage calibrated 2 to 10 lbs./in.^{2}, but reading in terms of rate-of-flow.

Fig. 2 shows the substitution of a shaped lever B' for the bell crank B of Fig. 1, and the addition of lever G. The unit is now capable of extracting the square root of the pressure differential across the orifice, and transmitting flow readings on an evenly divided scale. It is interesting to note that in this unit, where the pneumatic amplifications are the greatest (near zero flow), the contact angle of the levers is at a minimum. This illustrates how the pneumatic system produces a relatively high multiplication of motion with mechanical forces that are relatively low.

PRACTICAL EMBODIMENT

Fig. 3 shows a complete pneumatic telemetering system with several hundred feet of coiled tubing transmitting the readings to the receiving instrument. In this illustrated example, an air-operated automatic-control unit, operating a control valve, is located at the receiver, which takes the form of a recorder. Numerous other combinations may be made, such as the addition of a duplicate pneumatic system for resetting the control index in the transmitter from the receiving instrument. Also, the control unit may be located optionally in either instrument and the scale may be evenly divided on one and square root on the other. Either instrument may be made as a recorder or indicator, and the transmitter may consist simply of the units in a closed box known as a blind transmitter. For pressure or temperature transmission, it is merely necessary to replace the manometer in the transmitting instrument with the required measuring element.

OPERATING CHARACTERISTICS

Tests on the model illustrated in Fig. 3 brought to light the following operating characteristics.

(1) Because of the inherent sensitivity of the pilot system, as previously described, there is a definite pressure response for as low as 0.2% of the total manometer float movement. This would naturally suggest that such extreme sensitivity would set up an oscillatory condition. This was not the case, however, since the bellows acted instantly to correct for the change in pilot position, *i.e.*, each movement of the pilot set up forces to oppose that movement and the mechanism was found to be inherently stable. Wide changes were made without overshooting.

(2) The speed of transmission is practically directly proportional to the distance. A large size connecting tubing would cause a delay because of the volume, while a small size would be affected by internal friction. A 3/32" I.D. tubing has been found to be the optimum size for maximum speed. Since the air in the tubing and receiver bellows is static at the balanced pressure, the size of this tubing would in no way affect the accuracy. Using 200 feet as the transmission distance, the speed has been found to be 0.7 seconds for a 1% change in pressure. This becomes approximately 7 seconds for a 10% change and 20 seconds for full scale. This is faster than the normal speed of a manometer, but where required on special applications, it can be increased four to five times with the use of a booster valve of the conventional type supplied with air-operating controllers.

(3) As previously discussed, the forces available are dependent on the pressure range, size and stroke of the bellows. In this model, the pen torque was found to be $\frac{1}{2}$ in-oz. for 1% pressure change, or over three inch-pounds for full scale. This is more than sufficient for any normal condition.

(4) The air consumption was found to be 0.016 ft.^{3} of free air per minute. This corresponds to less than 10% of that used by the average air-operated controller now on the market.

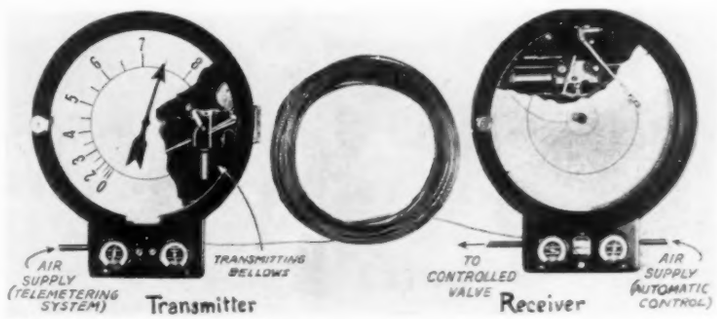

Fig. 3. Complete assembly of flow-rate telemetering system.

(5) Because of this low air consumption, the problem of maintaining operation at low temperatures is materially simplified: A calcium chloride dryer of 100 in.^{3} capacity will remove sufficient moisture to prevent freezing, even at sub-zero temperatures, for a period of six months of 24-hour service. The use of a booster valve would, of course, increase the air consumption and decrease the life of the dryer proportionately.

(6) Ambient temperature changes of 100° F. affected the accuracy of the readings by 0.3%. This test represents outdoor exposure of the entire system to summer and winter temperatures in a fairly harsh climate. Most

Continued on page 248

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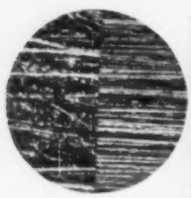

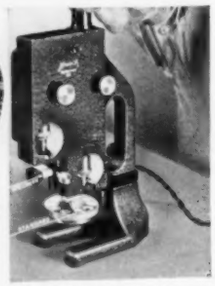

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INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

JULY PROBLEM (No. 9)
MEASURING FURNACE HUMIDITY

From the Chief Engineer of a mining-milling-refining company: "We have a furnace in which the temperature ranges from 650° to 1600° and wish to measure the humidity in the furnace atmosphere. We wish at least to determine the humidity from time to time by a sampling method, but it would be better if we could obtain a continuous indication and a chart record."

$5 PRIZE SOLUTION
By JOHN W. FULTON
NUTLEY, N. J.

Since it would be difficult to operate humidity measuring instruments directly at the temperature involved it would be best to draw a sample of the furnace gas outside to the measuring apparatus. To avoid condensation on cooling of the gases to room temperature, an excess of dried air may be added to the furnace gases so that the mixture, when cooled to room temperature, will not be saturated.

By measuring the amount of dry air added and the total amount of gas drawn out by the pump, the difference will be the amount of gas removed from the furnace. If the gas be passed through a weighing tube filled with one of the usual dessicants, the difference in weight of the tube before the test and after passing a definite volume of furnace gas through the tube will give directly the weight of water in the volume of gas passed through the tube, corrected at room temperature and pressure.

It will be necessary to select a dessicant which will not absorb anything else from the gases except water vapor. The domestic variety of gas volume meter may be used to measure the volume of dry air added and the total volume of gas passing through the drying tube. The drying tubes and dessicants are standard equipment used by organic chemists.

It should be possible to obtain a continuous record of the water content of the furnace gases by the use of two Pirani gage tubes and a recording Wheatstone bridge. The Pirani gage tube (such as G. E. No. FA 13) consists of a metal filament mounted in a glass tube with the walls near the filament. The temperature of the filament at constant impressed voltage, measured by its resistance, is a measure of the heat conductivity of the gas in the tube. Since the heat conductivity of water vapor is much greater than that of other gases apt to be in the furnace atmosphere, if the mixture of furnace gases and dry air be passed through one gage tube to measure its heat conductivity, then through a drying chamber (as above) and then through another similar gage, the difference in heat conductivity on removal of the water vapor will be directly proportional to the original water content of the furnace gases.

Since the standard Pirani gage is made to be used on vacuum systems it is tubulated at only one end. In order to pass the gas in more intimate contact with the filament it would be desirable to tubulate the gage tubes at both ends.

A standard recording Wheatstone bridge may be calibrated in weight of water vapor per unit volume of furnace gas by the previously discussed sampling method.

Visual rate-of-flow meters should be installed to measure the volume of the incoming dry air and total volume of gas passed through the measuring cells so that they may be kept constant.

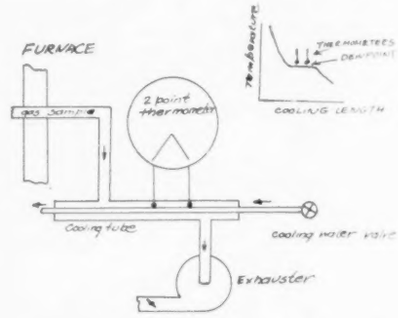
The two cells should be placed close together and maintained at a reasonably constant temperature.

For the sake of economy, the drying agent may be one of the regenerative kind, two drying cells being provided so that one may be regenerated while the other is in use. Care must be used to select a dessicant selective only for water vapor as in the sampling method.

The humidity as measured is the absolute water vapor weight per unit volume of furnace gas at room temperature and pressure. To obtain the relative humidity in the furnace atmosphere, the volume of gas must be corrected for the actual temperature and pressure existing in the furnace, and the absolute humidity in the furnace thus obtained converted to relative in the usual manner as a function of temperature.

$5 PRIZE SOLUTION
By ALFRED A. MARKSON
KEW GARDENS, N. Y.

If a continuous sample of furnace gas is drawn through the apparatus sketched, and cooled by a countercurrent of water, the temperature of the gas will fall until the dew-point is reached. Under this condition the gas temperature will remain



constant till condensation is fairly well advanced. The temperature will then fall as both sensible and latent heat are removed. By manipulating the gas flow and the water flow, this zone can be brought under the two thermometer bulbs. When the two bulbs coincide in temperature the temperature they read may be used as the dew-point. Reference to a curve of furnace temperature *versus* this temperature will give the relative humidity.

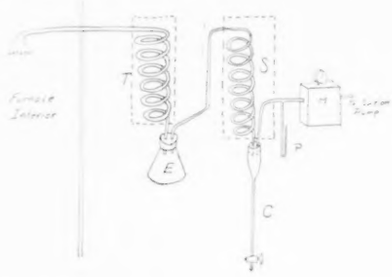
There will be no theoretical errors involved affecting process control. Indeed this type of apparatus may be used to investigate higher dew-points, such as of sulphuric acid, with a view to investigating the quantities of these substances.

The writer would be glad to undertake the actual design of the apparatus to make it indicating, spot recording or automatically and continuously recording.

$5 PRIZE SOLUTION
By HAROLD T. OLSON
MINNEAPOLIS, MINN.

Determination of the humidity of furnace atmosphere is stated to be complicated by the presence of other vapors and gases which would render chemical methods inoperative. Therefore, we cannot make use of chemical absorption tubes but must physically condense and measure the water contained in a measured volume of the furnace atmosphere, while at the same time we eliminate any other vapors or gases which might be present. Such considerations led to devising this system:

T and *S* are condenser coils which are held respectively at 50°C. and 5°C. *E* is an Erlenmeyer flash, *C* is a fine-bore burette measuring to 0.02 cm.³ directly



to which has been sealed at its upper end approximately 1" of large-diameter glass tubing. *P* is an open-end manometer which determines the pressure in *C* in terms of the barometric pressure and the height of the liquid in the two arms. *M* is a bellows type gas meter connected to a suction pump.

In operation, T serves roughly as a purification chamber in which the most readily condensable vapors are trapped and allowed to collect in the flask *E*. But *E* is held at approximately 100°C., hence any water which may have condensed in *E* will be distilled over into *S* where it condenses and drips into the burette *C*. To make a determination of the humidity in the furnace at any time, the level of the water in *C* and the reading of the meter *M* are determined. The pump is then turned on and allowed to run until a measurable amount of water has condensed in *C*. The humidity in the furnace chamber would then be:

$$H = \frac{(C-C_0)}{(M-M_0)} \frac{B}{(B-hD)} \text{ cm.}^3 \text{ } H_2O/\text{ft.}^3 \text{ air}$$

where:

C is the burette reading in cm.³,
M is the gas-meter reading in ft.³,
B is the barometric pressure,
h is the height of manometer column, and *D* is the density of the manometer liquid.

Since the air going through the meter will be saturated with water vapor at the temperature of the still *S*, a correction for the moisture carried through the system should be made by adding to the above-obtained value of *H* an amount equal to the cm.³ of water contained in 1 ft.³ of saturated air at 5°C.

An occasional check on the efficiency of the system can be made by analyzing the water in *C*: if an appreciable portion of CO_2, NO, etc., is present, the temperature of the condenser *T* should be adjusted to reduce these impurities.

$5 PRIZE DISCUSSION
By W. H. WRIGHT
WILMINGTON, DELAWARE

The thermal conductivity method of flue gas analysis is sensitive to moisture. By passing a stream of the flue gas through one conductivity cell, removing the moisture in a low-head scrubber train, and passing through a second thermal conductivity cell, the differential emf. between the two cells should be due to moisture only regardless of the composition (CO, CO_2, N_2, etc.) of the flue gas. If sulphuric acid is used in the drying train, unsaturated and oxygenated compounds would be absorbed. However, these are not likely to be present in appreciable quantities in flue gases from a furnace at the specified temperature range, and would therefore not introduce much error into the system. The equipment may be calibrated by gravimetric analysis of the gas passing through, *e.g.* absorption of a metered quantity in a phosphorus pentoxide tube.

Problem No. 11 — Subject Index 10

LOCATING BURIED TREASURE

We frequently are consulted on instruments for locating buried treasures. Most inquirers seem to be irresponsible. Among the exceptions, two prompt us to bring up this question as a Forum problem: (1) a well-known radio program director desiring a scientific basis for censoring assertions to be broadcast; (2) a properly-introduced person seriously concerned in a family matter involving a hoard of gold and silver articles. Both inquirers seem to desire *quantitative data* on the sensitivity and selectivity of each method. Expressing their requests in more exact terms, we would put it this way:

(1) For each method compute a table or plot a curve of least-weight-of-material *versus* greatest-distance-for-detection, using log-log grid.

(2) Give table or chart of selectivity, comparing ultimate sensitivity values with respect to different metals and alloys.

(3) Discuss sources of error, possibility of compensating, etc.

(4) Discuss other practical limitations of each method, including costs.

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INSTRUMENTS' BOOK SHELF

Instrument Transformers — Their Theory, Characteristics and Testing. By B. Hague. Pitman Publishing Corporation, New York, 1936. Cloth, $5\frac{5}{8} \times 8\frac{5}{8}$ inches, xxiv + 656 pages. Price $10.00.

As an attempt to provide a comprehensive review of this magnificent work would transcend the limitations of space, the reviewer must confine his remarks to a few comments based for the most part upon the author's own prefatory statements. The claim that there has heretofore been no complete analysis published in the English language of the literature dealing with instrument transformers is well founded; and in his effort to remedy this deficiency the author has succeeded in producing a remarkable book. The ultimate stimulus for its publication may lie, as is the case with a number of other recent British electrical books, in the amazing developments in large-scale power transmission which have taken place in Great Britain during the past decade under the Government-sponsored "Grid" system.

The author "has endeavored, as a teacher, to concentrate chiefly on an exposition of fundamental principles, illustrated by a description of apparatus in which those principles seem most satisfactorily to be embodied." The book deals primarily with transformers used in electrical measurement, those used in protective systems receiving only secondary consideration. Fundamental principles, rather than design details, form the basis of treatment. The subject matter is divided into five parts covering respectively: (1) Theory and Characteristics. (2) Apparatus for Testing; (3) The Testing of Current Transformers for Ratio and Phase-angle; (4) The testing of Voltage Transformers for Ratio and Phase-angle; (5) Additional Tests (such as polarity, overload, dielectric, etc.)

The work reflects a most conscientious and painstaking study of the whole field of instrument transformer practice without regard to any national bounds. The scope of the treatment ranges from the molecular and atomic structure of the material of the magnetic circuits to the interconnection of transformers for the measurement of polyphase power loads. No less than 116 pages are devoted to the determination of current transformer constants; and more than 50 pages to corresponding tests of voltage transformers. It would seem that the author has not overlooked any reputable method that has ever been described; and in discussing these he plays no favorites, but gives to each a full and unbiased treatment. By way of explaining the detail in which he has treated this branch of his subject, the author points out that, though a method may not have been found sufficiently suitable for its original purpose to justify its wide adoption, yet it may prove useful in other fields, and for this reason alone is worthy of being put on record. He also expresses the hope that the coördination provided by the bibliographical study given in this connection may do something to prevent in the future much unnecessary duplication of work.

A mass of informative material, not readily classified in the general scheme of the book, appears in nine short appendices; and in one of them the author has taken the reader into his confidence to the extent of providing an analysis of the periodical literature from which his references have been drawn, and showing a graph of the annual output of such literature on instrument transformers, beginning with Campbell in 1896. He uses this curve to confirm his theory that the instrument transformer has now so closely approached perfection that technical literature on the subject is henceforth likely to show a sharp decline. If this theory is sound the book seems to have appeared at a fortunate moment.

The work is profusely illustrated with 300 specially prepared diagrams, curves, and line drawings. The bibliography is most complete, the author having drawn from some 73 sources published in 12 different countries, and reference being made to 464 articles dealing directly with instrument transformers, beside a large number treating ancillary matters, such as the metallurgy of magnetic alloys and the design of testing equipment. The bibliographic index contains the names of nearly 400 authors; and the alphabetical index occupies 17 pages.

Dr. Hague's masterly treatment of this branch of electrical engineering fills a long-felt want in technical literature. It is at once informative and readable, and will undoubtedly be long recognized as an ultimate standard of reference wherever alternating current measurements are involved.

—Perry A. Borden, *Research and Development Engineer, The Bristol Co., Waterbury, Conn.* (4)-B-

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Fundamentals of Vacuum Tubes, by Austin V. Eastman. McGraw-Hill Book Co., Inc., New York, 1937. Cloth, 6 × $9\frac{1}{4}$ inches, xvi + 438 pages. Price $4.00.

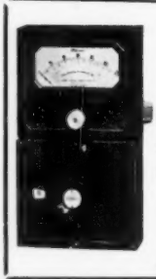
This book is primarily intended for use as a text by senior students who have had a thorough training in elementary electrical engineering and in mathematics through elementary calculus. The material included is up-to-date, well chosen and logically and effectively presented. Algebraic and graphical analyses are freely employed. Particularly commendable are the references and problems with which each chapter is provided. Appended is an author index as well as a subject index.

In three introductory chapters the author lays an excellent general foundation. Thereafter, about two-thirds of the book is concerned with the use of thermionic tubes in communication circuits. The remainder comprises an introduction to other engineering applications. Gas-filled and photosensitive tubes are fully discussed, and other special tubes are briefly noticed.

The treatment is so thorough that the book does not lend itself well to hasty consultation. The author's point of view is functional rather than structural; he presents electrical processes and their explanations, not electrical devices and their applications. Nevertheless, the student is encouraged and assisted toward design work, nineteen tables of practical data being provided.

In short, this is not a book for the outsider. It is a text for students of electrical engineering whose major interest is in electronics, and who intend to seek permanent employment in this field.

—Charles Williamson, *Professor of Physics, Carnegie Institute of Technology, Pittsburgh, Pa.* (5)-B-



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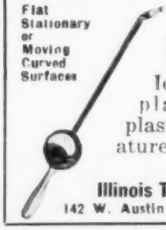

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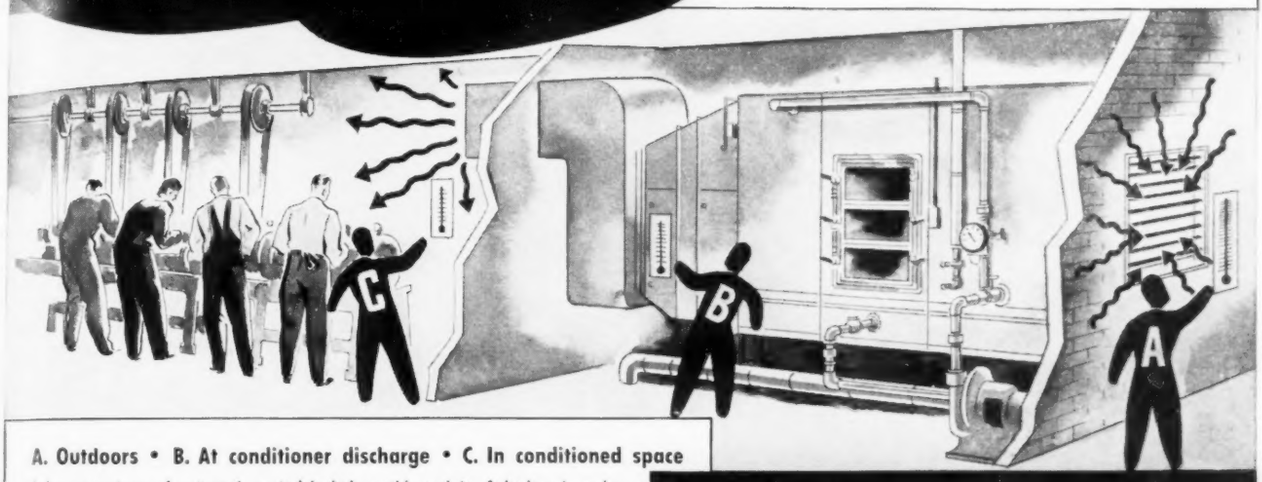

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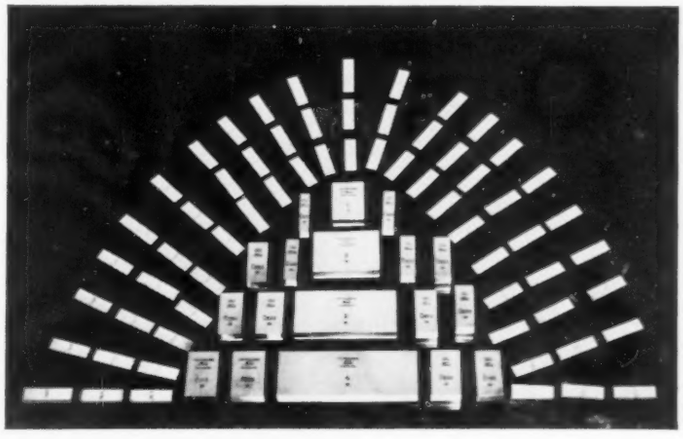

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PNEUMATIC TELEMETERING

Continued from page 243

actual installations would be subjected to smaller variations.

(7) A 25% change in the pressure of the compressed-air supply altered the receiver readings by less than 1% of full-scale.

(8) Normal vibration frequencies were found to have no effect on the accuracy of the readings. In a test in which the amplitude was so great that the entire flow-meter body vibrated violently, less than 1% change was shown at the receiver.

INDUSTRIAL ADVANTAGES OF PNEUMATIC TELEMETERING

(1) In the operation of many processes there is constant danger of the formation of an explosive atmosphere from leakage or other accidental causes. An electrical system then constitutes a serious hazard; a pneumatic system is inherently "explosion-proof."

(2) Flow-rate readings, in many cases, should preferably be indicated or recorded on an evenly-divided scale, rather than on the characteristic square-root scale. This is particularly true when automatic control is used. To accomplish this square-root conversion requires a high multiplying factor at low flows. For example, 10% flow is 1% of the full-scale pressure differential and 5% flow is only ¼ of 1% of this reading. This must accordingly be converted without loss of accuracy or power. The geometrical devices commonly used to make this conversion (shaped tubes, bells, etc.) have not been found practical, for evenly-divided readings, below 10 to 15% of flow. Moreover, they must be manufactured with extreme precision and installed in an absolutely level position. The pneumatic system is peculiarly adapted to performing this function over the entire range and with the use of a plain cylindrical "range tube" in the mercury-and-float manometer.

(3) In the measurement of high pressures, it is objectionable to pipe meter lines any unnecessary distance, not only from the standpoint of leakage and maintenance, but by reason of the additional hazard as well. Any telemetering system, of course, does away with long-distance high-pressure connections, but the pneumatic system introduces no other hazards.

(4) In the chemical industries, the elimination of extra piping of poisonous or corrosive fluids removes an additional danger.

(5) Fluids which become too viscous, at atmospheric temperatures, for accurate metering, offer another logical application.

(6) Extremely low pressures will have the forces available accurately amplified many times when the pneumatic transmission system is used.

(7) Temperature measurements, in which a liquid-filled bulb is required, may well use this system to avoid the inconvenience of not being able to disconnect the capillary during the installation or any subsequent changes which are found necessary.

(8) The problem of temperature compensation of the capillary is also eliminated.

(9) Any non-linear characteristics may be converted to uniform movement, as with the flow transmitter.

(10) An installation using a transmission distance greater than 200 feet will undoubtedly be found relatively economical, since commercial tubing of 3/32″ to ⅛″ I.D. is all that is required.

It is the author's hope that this article will help to stimulate interest in future development work to widen still further the scope of this type of transmission.